IN TWO SECTIONS—SECTION ONE

MECHANICAL ENGINEERING

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ANNUAL MEETING, NEW YORK, DECEMBER 2-5

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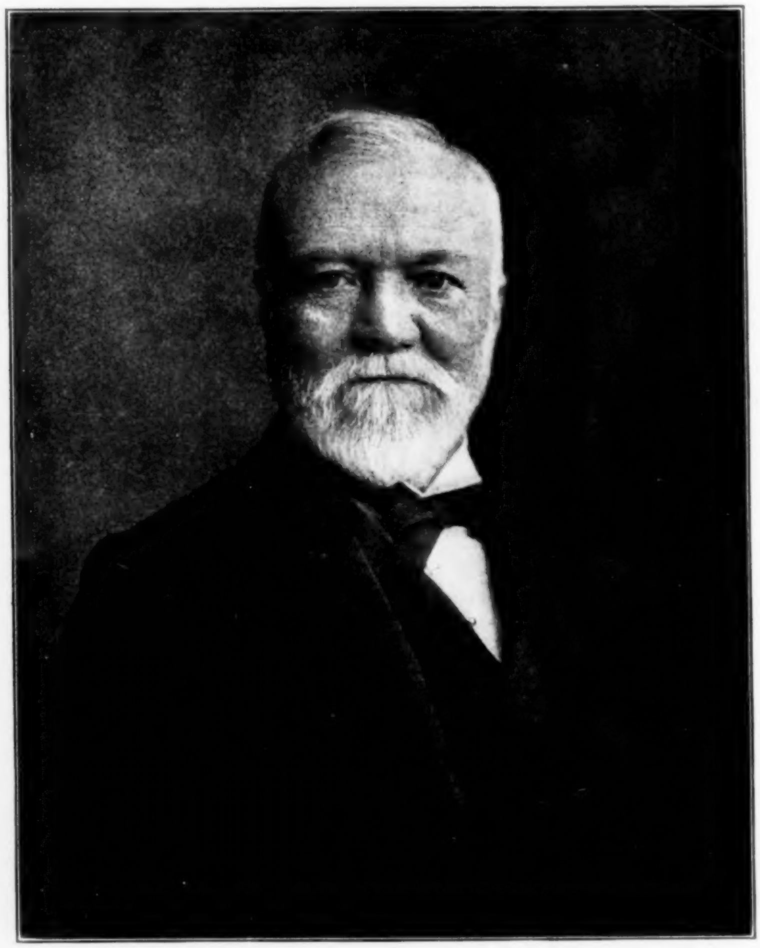

ANDREW CARNEGIE

DIED AUGUST 11, 1919

DONOR OF THE ENGINEERING SOCIETIES BUILDING
AND THE BUILDING OF THE ENGINEER'S CLUB
MEMBER OF THE SOCIETY FROM 1890
HONORARY MEMBER FROM 1907

Volume 41 Number 9

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

SEPTEMBER, 1919

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A. S. M. E. WAR SERVICE RECORDS

The committee appointed by The American Society of Mechanical Engineers to prepare a record of the service of its members in the late war has issued a circular outlining the data desired, to which the attention of the membership is called. The circular calls for information under the following headings, and an early response is urgently requested:

(1) What had you been doing immediately prior to your entering the service?

(2) What had been your education, training and experience up to the time you entered the service?

(3) On what date did you enter the service of the U. S., or any allied Government?

(4) If an officer, what was your rank and organization?

(5) If not an officer, and on war work in any department as a civilian, what were your duties?

(6) What were the duties to which you were first assigned?

(7) State subsequent transfers and where you were assigned in each case?

(8) If promoted to a higher rank, state that higher rank and the date of promotion, what transfers, place and character.

(9) What duties did you perform after your promotion?

(10) Were there any other promotions?

(11) If so, give particulars as above.

(12) Please state what professional reports, if any, were prepared by you, and name all boards or other bodies as a member of which, or to which, you rendered special service.

(13) Please give any further information that may be needed to form the basis of a complete account of your service.

(14) Did you serve overseas in any capacity, and what were your duties, and with what organization?

(15) Were you engaged in any combats?

(16) Where and what was your service in such, and were you wounded?

(17) Did you receive any medals, decorations, or awards? If so, please describe them.

(18) Are you still in active service?

(19) Are you now a reserve officer?

(20) If still in the service, do you expect to continue? As what, and in what organization?

(21) If you resigned or were discharged, please give date.

(22) Please send names and addresses of all other members of our Society whom you know of having rendered service during the war, either as civilians or otherwise, so that the Committee can get into communication with them.

(23) Please let us have your statement as soon as possible.

Lt.-Col. J. J. Swan,
Major William B. Gregory,
Major Fred J. Miller, Chairman
Committee on War Participation and Members' Memorial

THE ANNUAL MEETING

New York, December 2-5

The Committee on Meetings and Program desires advance information regarding papers which members have in preparation or are to contribute; and suggestions for papers or subjects for discussion.

It will be of the greatest assistance to have this information NOW, while plans are in process of development and before the program has been completely formulated. Members are requested to cooperate with the Committee by advising the Secretary promptly of paper prospects, thus helping to make the next Annual Meeting the greatest convention in the history of the Society.

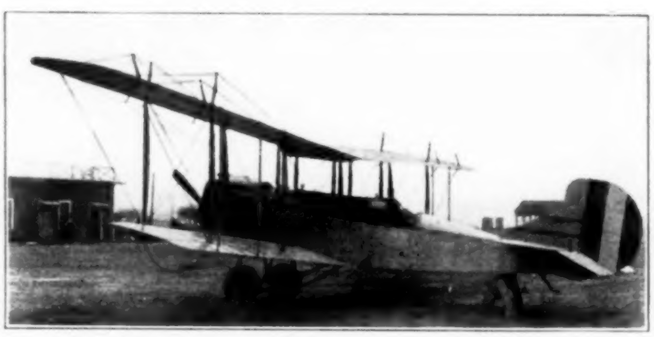
The Horsepower of Resistance in Aeroplane Design

By N. L. LIEBERMAN,[1] GARDEN CITY, L. I., N. Y.

THE problem of the resistance of an aeroplane has received, directly and indirectly, the analytical attention of many of the celebrated mathematicians and physicists of the last and present centuries. The researches of Newton and Bernoulli have given the general laws of motion and pressure; Euler presented the laws of fluid motion from an investigation of all the points occupied by the fluid, at all instants; while Lagrange explored the same field by investigating the motion of an individual particle. To Lord Kelvin we are indebted for his general dynamical principle. Helmholtz first solved the flow of fluids bounded partly by fixed walls and partly by surfaces of constant pressure and developed the formulæ of vortex flow; then independently and almost simultaneously Helmholtz and Kirchoff established the theory of discontinuity flow. In 1902 Kutta brought forward his vortex sustentation principle, for arched surfaces. A partial explanation of turbulent or eddy motion was presented by Prandtl. The elaborate mathematical analyses of Laplace, Raleigh, Schwartz, Christoffel, Rankine, Stokes, Lanchester and Lamb; and the experiments of Langley, Lanchester, Föppl, Prandtl, Reynolds and Zahm, have all contributed to a directive understanding of the phenomena of fluid motion. No attempt is herewith made to expand any of the above-mentioned theories. Complete discussions, showing the derivations and limitations, are given in Lamb's Hydrodynamics. An excellent résumé showing the salient features of each theory and the mathematical concepts was presented in 1915 by J. C. Hunsaker in his paper, A Review of Hydrodynamical Theory as Applied to Experimental Aerodynamics.[2] It is of interest, however, both academically and for guidance in experimental work, to know the results obtained by these various investigators.

Type No. 4, S.E. 5

Type No. 3, Bristol Fighter



Type No. 2, Curtiss J. IV.-4

Type No. 4, Curtiss R-4

Fig. 1 Four Different Types of Aeroplanes

Model Study and Dynamical Similitudes

The general condition of translational motion in one direction of a solid has been expressed by D'Alembert in the equation

$$M\frac{d^2s}{dt^2} = F \qquad [1]$$

where M = total mass of body

$\frac{d^2s}{dt^2}$ = change of rate of motion of mass M

F = impressed forces

$M\frac{d^2s}{dt^2}$ = effective forces.

Since this equation is independent of any assumption as to the character of the mutual actions and reactions between the particles, it is applicable to fluids as well as to solids. The problem, briefly stated, is the determination of the relations between the impressed forces on a full-scale body, of three dimensions, and its geometrical model.

A detailed examination of the characteristics involved in the complete definition of the body, fluid and motion, shows that only eight are ultimately needed to completely identify the motion for model study. These eight characteristics are—

$M\frac{d^2s}{dt^2} = F$ = force developed

L = span of aerofoil

ϵ = elasticity of aerofoil

ρ_1 = density of aerofoil

ρ_2 = density of fluid

Abridgment of a paper presented at a meeting of the Buffalo Section of The American Society of Mechanical Engineers, January 29, 1919.

[1] Asst. Mgr., Dept. of Education and Sales Promotion, Curtiss Aeroplane & Motor Corpn.

[2] Presented before the International Engineering Congress, September, 1915.

φ = kinematic viscosity of fluid
C = compressibility of fluid (velocity of sound in fluid)
V = velocity of advance of body (or fluid).

These terms are then treated in accordance with the theory of dimensional homogeneity. The basic principle of this theory is that all terms of an equation must be expressed in the same system of units. The M, L, T, notation is here used.

The physical equation

$$f\left(M\frac{d^2s}{dt^2}, L, s, \rho_1, \rho_2, \varphi, C, V\right) = 0$$

yields the final general expression

$$M\frac{d^2s}{dt^2} = F = \rho_2 L V^2 \psi\left[\frac{LV}{\varphi}, \frac{V^2\rho_2}{s}, \frac{\rho_2}{\rho_1}, \frac{V}{C}\right] \quad\ldots\ldots\ldots[2]$$

If the velocities of test do not approach the velocity of sound in the medium of test, and further, if the medium of test is the same as the medium of flight, the ψ function reduces itself to a consideration of the L and V factors. Since for any given model

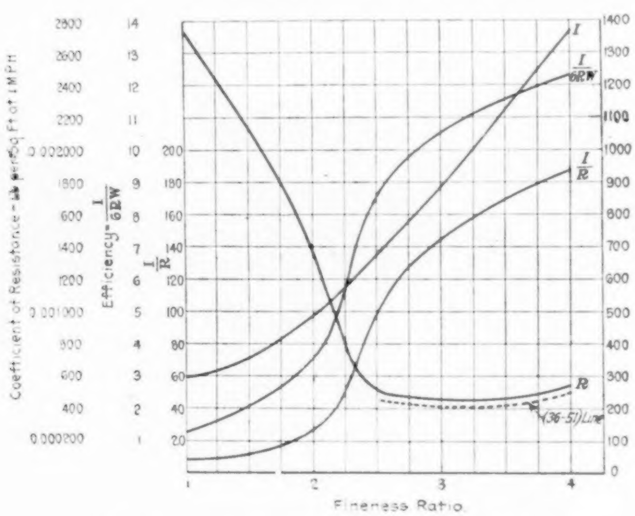


FIG. 2a COEFFICIENTS OF RESISTANCE OF STRUTS

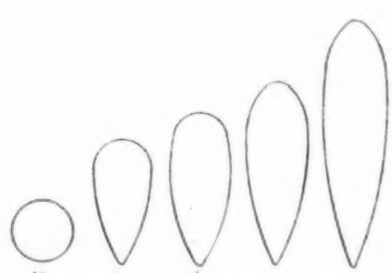


FIG. 2b CROSS-SECTIONS OF STRUTS USED IN PLOTTING CURVES OF FIG. 2a

L is constant, and for critical speed conditions we are governed by the relation $\frac{V}{V_m} = \frac{L_m}{L}$ (where L_m and V_m refer tc the line or dimension and velocity of the model), the ψ function becomes a constant. The statement for resistance is then given by the equation—

$$F = K\rho_2 L V^2$$

wherein K combines the effects of cross-section of the body, covering, attitude to flow of medium, etc. It is thus called the "form coefficient." For bodies other than of aerofoil type, interest lies mainly with the coefficient of resistance.

Coefficients of Resistance

Struts. In 1912 the N. P. L.[1] tested a series of proposed strut sections submitted by Mr. Ogilvie and obtained interesting results. In Fig. 2a the writer has assumed that a condition of continuity exists between struts of the same form-class, but of different actual length dimensions. In all cases the data plotted are always referred to the fineness ratio (length of cross-section divided by maximum width of cross-section). Fig. 2b shows the sections, dimensioned as to fineness ratio, that were used in plotting the curves of Fig. 2a.

Stream-Line Wires. When members are subject to vibration and movement so that they do not at all times present a head-on view to the wind, the effect on the resistance is similar to that experienced in a turn. Interplane wires are particular offenders in this respect.[1] Hence when stream-line wires were adopted, it was not sufficient merely to decide on a shape that offered the least head-on resistance.

Experiments with struts showed that for different angles of yaw the resistance of the best shape for head-on wind went up very rapidly with the change in angle. As a result of experiments on different shapes, for differing angles, the present generally elliptic shape was adopted. Fig. 3 shows the correction factor for different degrees of yaw.

Fuselage. The general design of the fuselage is frequently fixed by considerations other than those purely aerodynamic. The early forms with open framework are all now replaced with a continuously surfaced structure. Apertures are kept down to the minimum, since theory indicates and experiments show that these add to the total resistance by disturbing the stream-line flow. The main distinction in fuselages centers about the differences between the "short type plus tail booms," and the "long continuous type." The Farman and Voisin construction in French planes, the Vickers Gun-Bus and all the "FE" derivatives, are of the first class. Most of the fuselage construction, however, is of the long continuous type—even when the extended construction merely serves as a boom to the tail (cf. Caproni). The resistance coefficients now available on these various types are meager and disconnected. That is, knowing the coefficient for one form of fuselage does not materially help in determining the resistance of another form. The forms and coefficients given in Table 1 are

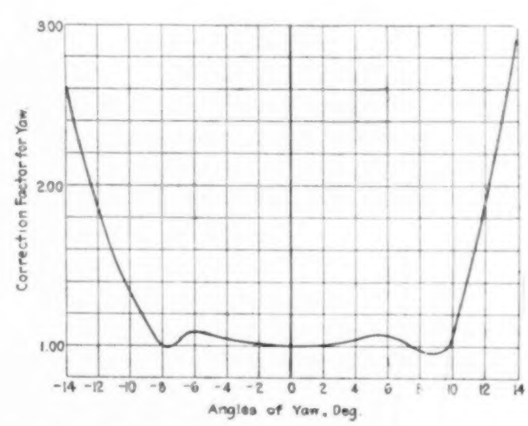


FIG. 3 CORRECTION FACTORS FOR DIFFERENT ANGLES OF YAW

the results of early and recent tests. The coefficients in the table are all for 1 sq. ft. of cross-section at a velocity of 100 m.p.h. (miles per hour), the fuselage inclined 6 deg. to the direction of the wind. The fineness ratio (maximum length divided by maximum depth) is also noted.

Panels

Extensive experimenting with models and full-scale machines has shown that the factors which for a monoplane form affect a saving are—

1 Wing curve
2 Aspect ratio
3 Plan form.

[1] National Physical Laboratory, Teddington, England.

[1] The vibration of round wires has no effect on the air-resistance—see Comparison of the Air Resistance of Vibrating Wires, by T. E. Stanton, in *Aerial Age*, October 18, 1915.

For multiplane arrangements the saving is a partial function of the monoplane, with increments due to

4 Stagger

5 Gap-chord ratio.

Wing Curve. The lift, drift, movement of the center of pressure and L/D cross-section of two well-known wing curves are shown in Figs. 4 and 5. For comparative study the L/D factors for these and other sections have been plotted in Fig. 6. The choice of a section depends completely on the service. Thus if a high carrying capacity at medium speed is wanted, the curve selected should have an L/D fairly constant over some appreciable range in angle of incidence. If a quick rise is desired at low speed, the lift coefficient at the larger angle of incidence should be high. On the contrary, if a high-speed machine is wanted, but also with a quick get-away (hence fairly low landing and taking-off speed), the L/D factor should be high at both the low and high angles of incidence. Since the weight of the machine is constant, the drift, which is one of the main factors affecting speed, will equal the weight divided by L/D. Hence the larger the L/D ratio, the smaller is the drift, and consequently less horsepower is required to attain, or maintain, a certain high speed.

Aspect Ratio. The more area that can be brought within the province of two-dimensional flow (parallel to the fore-and-aft vertical plane of symmetry), the greater will be the total value of L/D for the entire machine. This is obvious since the end flow of the air at the ends of the panels destroys the lift locally; and by creating probable surfaces of discontinuity within the panel region, still further increases the drift. Tests have shown that the L/D factor increases with the aspect ratio. However, there are both structural and dynamical considerations which limit the aspect ratio. The average practice of today indicates for ordinary two-place single-motor machines of velocity 75-90 m.p.h., an aspect ratio of about 7.0 to 7.5; for two-place single-motor machines of velocity about 125 m.p.h., an aspect ratio of about 6.0 to 7.0; for single-place machines, 100 m.p.h., an aspect ratio of about 6.0 to 6.5; and for single-place machines, 125 m.p.h., an aspect ratio of 5.0 to 5.5.

TABLE 1 RESISTANCE COEFFICIENTS FOR VARIOUS TYPES OF FUSELAGES

Fuselage	Length ÷ Depth	Resistance, Lb per Sq. Ft.	Fuselage	Length ÷ Depth	Resistance, Lb per Sq. Ft.
FARMAN NO. 1 (NO RADIATOR)	3.2	6.53	F.E. 2B.	4.6	13.88
FARMAN NO. 2 (NO RADIATOR)	3.2	8.56	F.E. 2C	4.6	13.05
FARMAN NO. 3 (NO RADIATOR)	4.3	14.60	F.E. 8	3.1	10.00
DEPERDUSSIN (OPEN MOTOR)	5.3	10.20	DEPERDUSSIN (COVERED MOTOR)	5.2	7.55
S.E. 4 A	4.7	4.92	S.E. 5.	5.6	12.85
B.E. 2 C	7.2	15.71	B.E. 3	6.2	8.65
AVRO	6.8	11.10	F.E. 7	7.6	5.91
STREAMLINE (ROUND SECTION)	6.4	3.80	STREAMLINE (ROUND SECTION)	6.4	4.98
STREAMLINE (SQUARE SECTION)	6.0	4.08	STREAMLINE (SQUARE SECTION)	6.0	5.35

It is customary to run wind-tunnel tests on panels having an aspect ratio of 6. The Report of the British National Advisory Committee for Aeronautics for 1911-1912 published correction factors for different aspect ratios, for individual angles of incidence. Within reasonable percentages these relative factors of correction for each angle of incidence have been found to be constant.

Plan Form. While early aeroplane builders attempted to follow the outlines of bird wings, and this still persisted in the early German Taube design, wind-tunnel tests have shown that both stability and good lifting capacity do not always go together for all types of cross-sections tested. Direct comparative tests on all types of plan forms show that the loading on the complete wing is independent of the form of the tip. While it would appear that

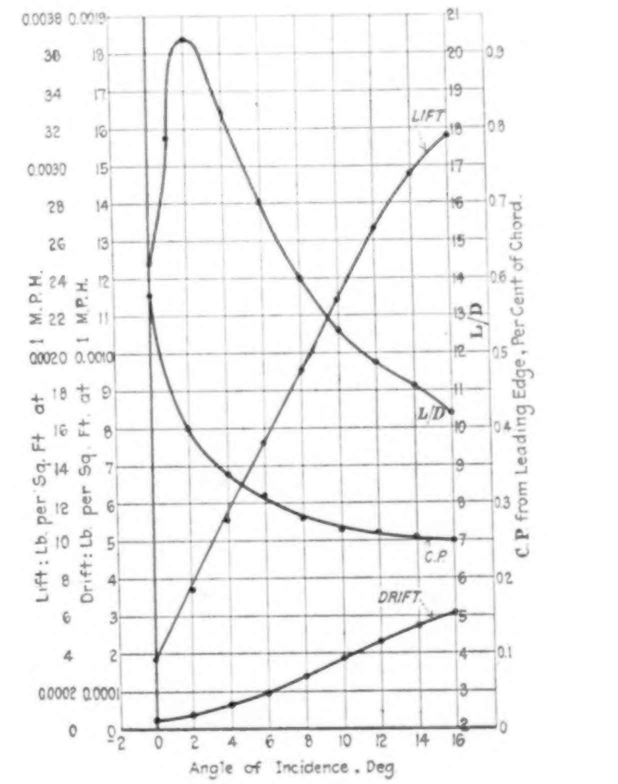


FIG. 4 VARIATION OF LIFT, DRIFT, C.P. AND L/D WITH ANGLE OF INCIDENCE, R.A.F. NO. 15

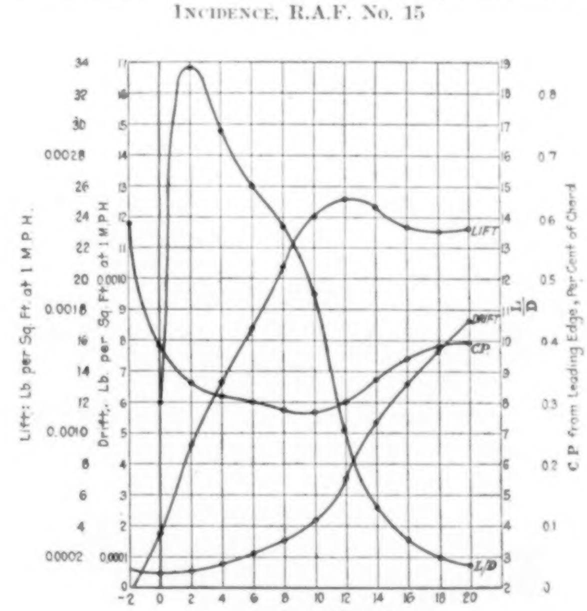


FIG. 5 VARIATION OF LIFT, DRIFT, C.P. AND L/D WITH ANGLE OF INCIDENCE, U.S.A. NO. 16

for different forms the region of disturbance should vary and hence affect the total loading, undoubtedly the three-dimensional flow masks small regional effects. Tests on a variety of round-ended panels show that a plan form, the end of which is a semi-ellipse, with the major axis normal to the chord and equal to 1.5 times the chord, gives the best results.

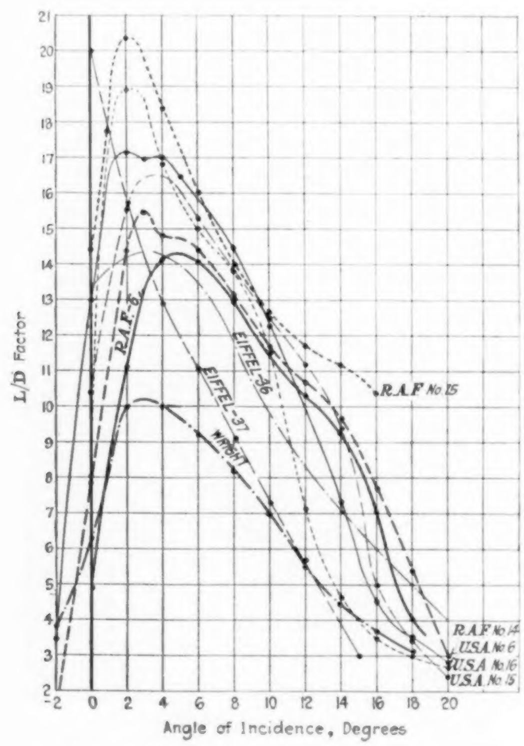


Fig. 6 Variation of L/D Factors of Various Sections with Angle of Incidence

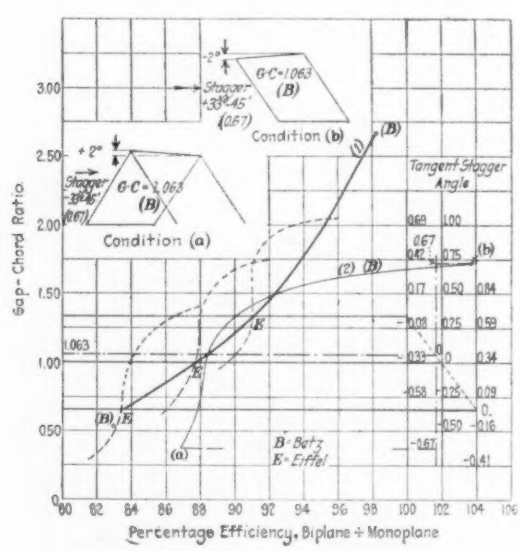


Fig. 7 Efficiency of a Biplane in Terms of an Equivalent Monoplane for Different Values of Gap and Stagger

Stagger and Gap. Many experiments with models and tests on full-scale members have been made in an attempt to reach reliable data showing the effect of the interrelated quantities chord, gap and stagger. M. Eiffel, the N. P. L. and Göttingen have collected considerable data on models in which these quantities were varied singly and readings taken for different angles of incidence.

The writer has taken Eiffel's and Betz' (Göttingen) results and from them constructed a series of curves, Fig. 7, which give the efficiency of a biplane in terms of an equivalent monoplane—permitting variation in both gap and stagger. The abscissæ are always percentage efficiency. The coördinates at the left give the gap-chord ratio. At any specific ratio a horizontal line was drawn, upon which was plotted the specific value of the percentage efficiency found by Eiffel or Betz for condition of "no stagger." The solid curved line (1) thus drawn through these points plotted on the various gap-chord ratio base lines represents the variation in percentage efficiency with changes in gap-chord ratio when the stagger is not considered (i.e., when the stagger is zero). If an auxiliary coördinate line be erected at the right-hand end of any gap-chord ratio base line previously drawn, and the tangents of the stagger angles be marked off as coördinates (positive and negative with respect to the base line), a new set of reference lines are thus established, based on the main set. The point for zero stagger has been set previously and occurs when line (1) intersects the gap-chord ratio base line. This point is now made the origin for another curve showing the variation in efficiency, as the stagger changes—while the gap-chord ratio is held constant. In this manner a series of curves are drawn through curve (1), each showing the variation of efficiency with stagger, for a specific gap-chord ratio. The three values plotted correspond to 1.33, 1.00 and 0.66 gap-chord ratios. Curve (2) shows the variations found by Betz for a gap-chord ratio of 1.063 when the stagger and angle of incidence were changed from condition (*a*) to condition (*b*).

In general, the values given by these curves are slightly higher than some of the other tests published; but within the range of ordinary usage the variation will generally be found less than one per cent. One point to be noticed is that for a gap-chord ratio of 1.0 (no stagger) the efficiency is quoted at 87.7 per cent, whereas recent tests have given the efficiency for these conditions at 84 per cent. Figures on the various properties of triplanes were published by J. C. Hunsaker, of the Massachusetts Institute of Technology.

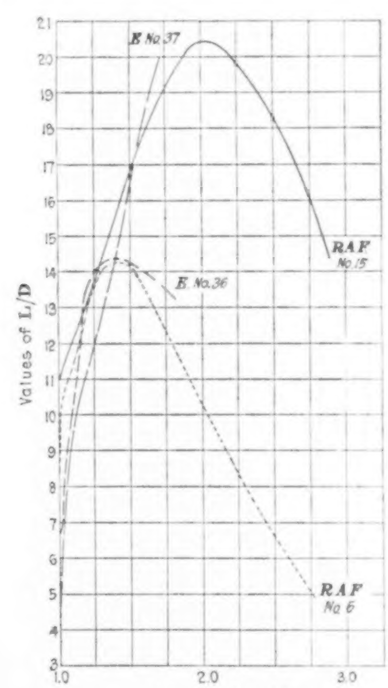


Fig. 8 Curves Showing Relation Between Effectiveness and Landing Speed

Panel Area and Resistance

The total panel area required in any aeroplane is a function of (1) the aerofoil, (2) the weight, and (3) the minimum velocity. The maximum speed, however, is a function of the resistance. Therefore every augmentation in lifting capacity for a given area is a conservation of horsepower and increases the efficiency of the machine (since the "resistance area" will be kept constant).

If the landing speed be called V_1, we have the relation

$$A = \frac{W}{k_1 V_1^2}$$

giving the area that must be furnished in the panels to sustain flight at the given minimum speed. If the minimum velocity be known, the minimum area will be required at the angle of incidence of greatest value of k_1 (k being the lift coefficient of the aerofoil). The maximum speed cannot be predicted until the details of the component parts of the machine are known and the resistance summated. However, assuming that any disturbing moment that would tend to vary the angle of incidence were controlled by the elevators or other means, so that the movement of the aeroplane were horizontal, the velocity at any angle α can be determined by substituting the corresponding value of k_a in the general equation.

$$W = k_a A V_a^2$$

in which W and A are already known, and k_a is selected from the "aerodynamic property" of the aerofoil with which the machine is equipped. Therefore any required velocity for sustentation at any angle other than the landing angle (provided sufficient power is available to overcome the resistance) may be expressed as

$$V_a = \sqrt{\frac{W}{k_a A}}$$

Substituting the value of A as previously found,

$$V_a = V_1 \sqrt{\frac{k_1}{k_a}}$$

Thus the maximum attainable velocity depends on the sum total resistance of the machine and the available power delivered through the propeller. That aerofoil which will sustain the total weight at the given minimum velocity and which will offer the least resistance at the maximum velocity, is therefore the economical one.

From the preceding equation and the aerodynamic coefficients of lift and drift of aerofoils, the effectiveness (L/D) of aerofoils at various speeds for any machine of known weight can be compared.

The resistance of the panels at any speed is equal to the total weight of the machine divided by the L/D factor for the angle of incidence that yields the given speed; or

$$R_a = \frac{\text{Weight}}{\left(\frac{L}{D}\right)_a}$$

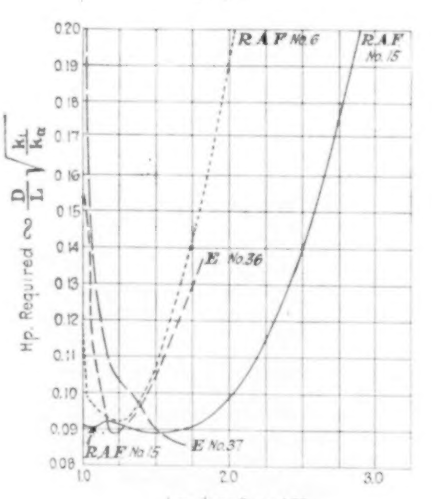


FIG. 9 RELATION BETWEEN HORSEPOWER REQUIREMENTS AND LANDING SPEED

Since the required horsepower $= RV/375$, where R is stated in pounds and V in miles per hour,

$$HP_a = \frac{\left[\frac{W}{\left(\frac{L}{D}\right)_a} \times V_1 \sqrt{\frac{k_1}{k_a}}\right]}{375}$$

which may be written

$$HP_a \sim \left(\frac{D}{L}\right)_a \sqrt{\frac{k_1}{k_a}}$$

The horsepower required for any type of wing curve can thus be plotted for various speeds (in terms of the landing speed). Fig. 8 shows the relation between the effectiveness (L/D) and

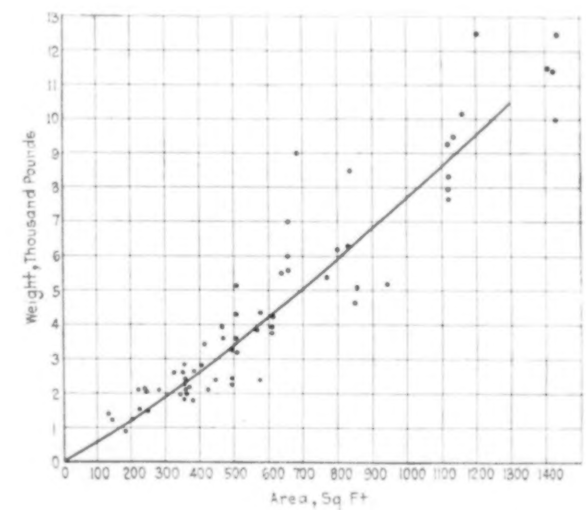


FIG. 10 VARIATION OF AEROPLANE SIZE WITH WEIGHT

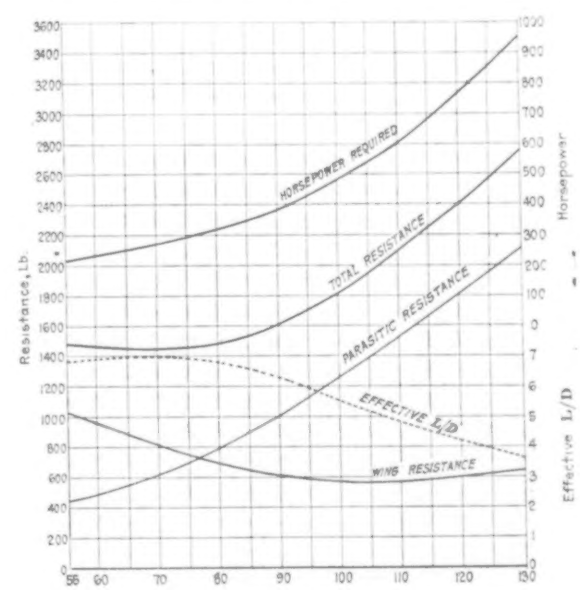


FIG. 11 PERFORMANCE CURVES OF A 10,000-LB. FLYING BOAT (R.A.F. No. 15)

various speeds for different types of curves; Fig. 9 shows the relation between the horsepower requirements and various speeds for the same types of wing curves.

A graphic method is thus presented which permits a direct comparison of the performance of several wing curves, both as to lifting capacity and horsepower consumption at various speeds. Fig. 8 shows that for high speeds the R. A. F. No. 15 wing curve has the greatest L/D; hence for any given machine weight, at high speeds, it will offer the least resistance. Fig. 9 shows that for practically all speeds the horsepower consumption of the R. A. F. No. 15 is least. Hence this wing curve is the most

economical of the four presented at high speeds. The same superiority is evident at low speeds, hence this wing curve is the best all-around curve.

Fig. 8 shows that for low speeds the L/D values of the R. A. F. No. 6 are greater than for the E. No. 36; whereas at the higher speeds the E. Nos. 36 and 37 are superior (the R. A. F. No. 15 excepted).

The curves of Fig. 9 show that for the lower speeds the R. A. F. No. 6 consumes less horsepower than either the E. No. 36 or No. 37. The reverse condition obtains at the higher speeds. Hence for heavy machines the high speed of which will not exceed 1.5 V (V = low or landing speed), the R. A. F. No. 6 curve is preferable to that of either the E. No. 36 or No. 37. Of these last two the E. No. 36 is better at lower speeds but inferior at higher speeds. Unless considerable excess horsepower be available with the E. No. 37 at getting-off speed, this curve is uneconomical.

Distribution of Horsepower Consumption

There is no fixed ratio in accordance with which the total horsepower requirements can be resolved for the component parts of an aeroplane. The following, however, appears to be true for four types studied (see Fig. 1):

1 The percentage of total horsepower consumed by each component group is dependent on the type of group and machine

2 The percentage of total horsepower consumed by each component group is generally independent of the weight of the machine

3 The panels show a decrease in requirement with increasing speeds

4 The remaining component groups show increasing requirements with increasing speed

5 The panel percentage requirement increases in any given type for increases in weight, whereas the percentages of the remaining groups decrease

6 The range of percentages of total horsepower requirements for the different groups, at increasing speeds, is of the following order:

		Per Cent
a	Panels	80 to 25
b	Panel accessories	5 to 25
c	Landing gear	3 to 17
d	Tail units	2 to 15
e	Fuselage	10 to 45

A general statement of "parts resistance," or horsepower requirements, cannot logically be made without considering both type and velocity.

Burden Distribution

The preceding figures have given the actual percentages of total horsepower per group without regard to the weight of the group with respect to the machine. In Table 2 it will be noticed that the percentage weight (of total machine weight) varies for each group, both for machines of the same type and for machines of different types. This variation may be due (*a*) to construction, (*b*) to loading of machine, or (*c*) to both. A curve which will show the relative horsepower expense of each group for its weight the writer has called a "burden curve." Thus a part or group which constitutes a very small percentage by weight may be very expensive in horsepower consumption in proportion to its weight. This curve is obtained by plotting as ordinates the values obtained in dividing the "percentage horsepower consumption," of each group, at various speeds, by the percentage weight of the part or group; and as abscissæ, the speed in m.p.h. Such curves show that:

1 The burden of the panels decreases with increasing speeds

2 The burdens of the other groups increase with increasing speeds

3 The panel accessories have generally the largest burden-figure of all groups

TABLE 2 DATA ON WEIGHTS, SPEEDS AND PANEL AREAS OF AEROPLANES

Machine		Gross wt., lb.	Gross panel area, sq. ft.	Speed range, m.p.h.		Parts, Percentage of Total Weight					Wing Curve No.
No.	Type			Low	High	Panels	Panel accessories	Landing gear	Fuselage	Tail	
3	2	2100	352.0	50	95	14.35	4.87	3.43	75.0	2.41	Eiffel No. 36
4	2	2400	352.0	50	95	12.55	4.20	3.00	78.1	2.11	Eiffel No. 36
5	3	2750	416.0	55	125	11.50	2.07	5.45	78.8	2.16	R.A.F. No. 15
6	3	3650	416.0	55	125	8.66	1.56	4.11	84.0	1.63	R.A.F. No. 15
7	4	3650	505.0	55	105	11.40	2.74	4.60	79.6	1.67	R.A.F. No. 6
8	4	4300	505.0	55	105	9.66	2.33	3.91	82.5	1.41	R.A.F. No. 6
1	1	1800	246.0	55	125	10.30	2.78	5.00	79.8	2.00	R.A.F. No. 15
2	1	2050	246.0	55	125	9.06	2.44	4.39	82.2	1.76	R.A.F. No. 15
9	2	2100	280.0	50	110	9.33	3.10	4.56	80.2	2.52	R.A.F. No. 15

4 The burden of the fuselage is practically constant for different speeds

5 In any one type an increase in weight increases the burden of the panels and decreases the burden of the remaining groups.

In interpreting "burden curves" the precaution should be borne in mind that these curves are functions of the percentage weight of a part besides the resistance. Thus, while the form of a group may be unchanged (hence the aerodynamic property unaltered, and the horsepower requirement kept constant), the internal construction may be altered to reduce its weight. The weight percentage of the group thus decreases and the burden figure increases (burden = per cent hp. ÷ per cent weight). A high burden figure may thus be due to either (*a*) a high resistance or (*b*) a low weight. In either event it serves as an index to the relative horsepower expense of the groups and shows where improvement may be centered.

Flight at High Altitude

The general formula [2] obtained in the discussion on dynamic similitudes showed that the density of the medium affected the dynamic reaction:

$$F = \rho_2 L V^2 \psi[\ldots.]$$

The density of the atmosphere decreases as the altitude increases. The weight of the machine remains practically constant with increases in altitude within the field of operation, hence if ρ_0 = density at sea level and ρ_h = density at altitude h,

$$W = \rho_h k A V^2_0 = \rho_h k A V^2_h$$

from which

$$V_h = V_0 \sqrt{\frac{\rho_0}{\rho_h}}$$

that is, the velocity at altitude h increases in the proportion $\sqrt{(\rho_0/\rho_h)}$ over the velocity at sea level. Also

$$D_h = \rho_h k A V^2_h = \rho_h k A \left(\frac{\rho_0}{\rho_h}\right) V^2_0 = \rho_0 k A V^2_0 = D_0$$

that is, the drifts (hence thrusts) remain constant at the respective velocities for any given altitude of the machine. Again,

$$\mathrm{HP}_h = \mathrm{HP}_0 \sqrt{\frac{\rho_0}{\rho_h}}$$

or the horsepower requirements at altitude h increase in the proportion $\sqrt{(\rho_0/\rho_h)}$ over the horsepower requirements at sea level.

Recent motor tests conducted under reduced pressure to obtain the equivalent condition to altitude, showed a decrease in power in the motor proportional to $(\rho_h/\rho_0)^{1.1}$. The efficiencies of propellers at different altitudes by tests were found to be

$$\eta_h = \tfrac{1}{2}\left[1 + \sqrt{\frac{\rho_0}{\rho_h}}\right]\eta_0$$

The motor output or available thrust at altitude h is $P_h \times \eta_h$,

therefore

$$P_h = \tfrac{1}{2}\left(\frac{\rho_h}{\rho_o}\right)^{1.1}\left[1+\sqrt{\frac{\rho_o}{\rho_h}}\right]\eta_w P_o$$
$$= \tfrac{1}{2}\left[\left(\frac{\rho_h}{\rho_o}\right)^{1.1}+\left(\frac{\rho_h}{\rho_o}\right)^{0.6}\right]\eta_w P_o$$

The quantities P_o and P_h represent the motor horsepower, as indicated in power curves; HP_o and HP_h represent the horsepower requirements for motion. Hence such value of ρ_h as makes $HP_h = P_h$, indicates the limit of climb, or ceiling of the machine. Combining the foregoing "available horsepower" statement with $HP_h = HP_o\sqrt{(\rho_o/\rho_h)}$,

$$HP_o = 0.5\left[\left(\frac{\rho_h}{\rho_o}\right)^{1.6}+\left(\frac{\rho_h}{\rho_o}\right)^{1.1}\right]\eta_w P_o$$

which is an expression for the ceiling of a machine when the available power and required power at sea level are known.

TRANSATLANTIC FLIGHTS

Recently aeronautical activities have been centered on large flying boats as a means for crossing the Atlantic. What follows, therefore, constitutes a study on the probable size of craft, fuel load and power equipment necessary to accomplish this trip, based on the data and performances of similar craft.

If η_i = efficiency of the propeller system
P_o = motor output in horsepower
n = number of motors

the available power $= \eta_i n P_o$, which in flight equals the power required, or $VD/375$. Since $D = W/(L/D)_e$, where the subscript e denotes "effective,"

$$\text{Available power} = \eta_i n P_o = \frac{VW}{375}\left(\frac{D}{L}\right)_e$$

By definition, the total weight is

$$W = nM + L_a + 160p + 6.15\lambda$$

where nM = weight of n motors
L_a = weight of aeroplane
$160p$ = weight of crew numbering p
6.15λ = weight of λ gal. of fuel.

If the motor consumption in gasoline and oil be γ lb. per b.hp., for n motors of P_o hp. each the consumption per hour will be $\gamma P_o n$ and the fuel will then last $(6.15\lambda/\gamma P_o n)$ hours at full throttle and maximum speed. The range of flight, with all n motors going, is in general terms $6.15\lambda V/\gamma P_o n$. If in this expression the values of $P_o n$ and W be substituted,

$$\text{Range (in miles)} = \frac{6.15\lambda V}{\gamma\,\dfrac{WV}{375\eta_i}\left(\dfrac{D}{L}\right)_e} = \left(\frac{L}{D}\right)_e\frac{6.15\lambda V\times 375\eta_i}{\gamma WV}$$
$$= \left(\frac{L}{D}\right)_e\frac{2306.25\lambda\eta_i}{\gamma(nM+L_a+160p+6.15\lambda)}$$

From Fig. 10, if the equivalent linear dimension be designated by $A^{0.6}$, where A = area, the weight will be proportional to $A^{2.6/2.0}$. The weight of the aeroplane can then be expressed as $L_a = \mu W^{2.6/2.0} = \mu W^{1.3}$. The motor weight, when expressed in terms of the available power, is $nM = vP_o n$, where v is the unit weight per b.hp. Therefore,

$$W = v\left(\frac{D}{L}\right)_e\left(\frac{WV}{375\eta_i}\right)+\mu W^{1.3}+160p+6.15\lambda$$

If now cW be substituted for $(160p+6.15\lambda)$, the following complete expression in W will result:

$$W = \frac{v}{\eta_i}\left(\frac{D}{L}\right)_e\left(\frac{WV}{375}\right)+\mu W^{1.3}+cW$$

Dividing this equation by W,

$$1 = \frac{v}{\eta_i}\left(\frac{D}{L}\right)_e\left(\frac{V}{375}\right)+\mu W^{0.3}+c$$

hence $c = 1 - \dfrac{v}{\eta_i}\left(\dfrac{D}{L}\right)_e\left(\dfrac{V}{375}\right) - \mu W^{0.3}$

In flying-boat construction the dead load of the hull, panels, etc., will constitute at a minimum about 35 per cent of the total load, or $L_a = 0.35W$. But as L_a has been shown to be equal to $\mu W^{1.3}$, $0.35W = \mu W^{1.3}$, from which

$$\mu = \frac{0.35}{W^{0.3}}$$

Assuming for W the approximate value of 25,000 lb.,

$$\mu = 0.0015$$

The propeller efficiency may be taken at about 80 per cent and a current value of 2 lb. per b.hp. for v. For the complete machine the L/D value will be of the order of 6.9 for the maximum values.

If a velocity of about 115 m.p.h. be approximated and the foregoing values substituted in the expression for c,

$$c = 1 - \frac{2.00}{0.80}(.145)\left(\frac{115}{375}\right) - 0.35$$
$$= 0.54 \text{ maximum to } 0.50 \text{ average}$$

If a crew of four men be included = 640 lb. = $0.026W$, the fuel may be regarded as $0.475W$ to $0.50W = 6.15\lambda$.

Range of operation (miles)

$$= \left(\frac{L}{D}\right)_e\frac{375\eta_i\times cW}{\left[v\left(\dfrac{D}{L}\right)_e\left(\dfrac{WV}{375\eta_i}\right)+\mu W^{1.3}+0.026W+cW\right]\gamma}$$
$$= \left(\frac{L}{D}\right)_e\frac{375\eta_i c}{\left[\dfrac{v}{\eta_i}\left(\dfrac{D}{L}\right)_e\left(\dfrac{V}{375}\right)+\mu W^{0.3}+0.026+c\right]\gamma}$$
$$= \left(\frac{L}{D}\right)_e\frac{375\eta_i c}{\gamma}$$

The highest (present design) theoretical value of the effective L/D is of the order of 9.0. For flying boats the value of this factor is considerably lower—more generally of the order 6.8 to 7.0. If an average value of 6.9 be assumed, with $\eta_i = 0.80$, $c = 0.50$, and $\gamma = 0.525$, the range of operation becomes

$$6.9\,\frac{375\times 0.80\times 0.50}{0.525} = 1975 \text{ miles}$$

The distance between Newfoundland and Ireland is in round figures 2000 miles, and preceding computations show that a machine of the given characteristics would just be able to cover the flying distance.

If an increase in size be contemplated so that c may attain a value of about 0.52 and the efficiency of large-diameter propellers be reckoned at 0.82 (this value has been consistently obtained in recent designs by the writer),

$$\text{Radius} = 6.90\,\frac{375\times 0.82\times 0.52}{0.525} = 2100 \text{ miles}$$

If all quantities be taken at their extreme values, a maximum range of 2300 miles is obtainable, giving an excess for deviation in flight of 15 per cent.

The results obtained in the foregoing calculations will now be compared with the performance curves of a 10,000-lb. flying boat, Fig. 11, and deductions as to size, capacity and flying speeds will be made. The model in question carries 330 U. S. gallons of gasoline. Equipped with two Liberty motors it would have a maximum speed of about 110 m.p.h. This gives a straight-ahead flying range of 550 miles, both motors working. It is thus obvious that at least 4.5 to 5.0 times as much fuel must be carried in a craft of this type to make the trip possible. Hence the fuel load must be $330\times 5.0 = 1650$ U. S. gallons of gasoline on a two-motor assumption. This corresponds to a load of 10,150 lb. (on the assumption of two motors). Hence if the machine be equipped with n motors the total gasoline load will be 10,150 $(n/2)$ lb.

From the above considerations the indications are that the new machine will be roughly 2.5 times the weight of the first, and about 1.75 times as large. Hence the horsepower requirements may be estimated at $\dfrac{m\sqrt{m}}{N}$ $HP_b = 2.25$, say, 2.0, where m = ratio of weights, and $HP_a = 2.0HP_b = 2\times 2$ motors. We can thus

(Continued on page 792)

ELEMENTS OF A GENERAL THEORY OF AIRPLANE-WING DESIGN

By WALTER C. DURFEE,[1] BOSTON, MASS.

This paper presents in brief outline form ten subjects which have reference to the theory of fluid motion around the wings of airplanes. These are: the vortex theory of lift; the theory of initial motion around wings; vortex theory of shape; hydrodynamic-electromagnetic analogy; action of vortices with reference to each other; action on vortices with reference to their images; influence of the local wind; laws of energy content in trailing vortex; friction and head resistance; and explosion of eddies. These various subjects are not discussed but are merely brought forward for the purpose of providing a starting point for discussion.

THERE are several subjects which seem so interesting in connection with a study of the action of wings upon the air that the writer has thought it valuable to the Society to place them on record, in brief outline and in such a way as to provide a starting point for discussion and the addition of any data which members of the Society may wish to contribute. These subjects which have reference to the theory of fluid motions around the wings of airplanes are as follows:

a The vortex theory of lift, which states that the air which passes the wing of an airplane, or the blade of a propeller, contains a component of circulation around that wing or blade, in such a direction that there is a comparatively high velocity and low pressure on the upper surface of a wing, and a comparatively low velocity and high pressure on the under surface.

b A theory which states that an imperfect fluid will act like a perfect one momentarily; from which it may be inferred that the circulation around a wing cannot exist at the first moment or beginning of its motion of advance but must develop at some time after the first beginning of the motion, since there is no circulation in the beginning.

c The vortex theory of shape, which treats of a solid body in motion as being somewhat similar to the core or kernel of a group of vortices.

d The hydrodynamic-electromagnetic analogy, which states that distributions of fluid motion are very similar to distributions of magnetic flux; so that one may calculate the fluid motion around a supposed vortex or group of vortices mechanically, by arranging electric currents or groups of currents in a manner analogous to the supposed vortices, and measuring the magnetic forces which result.

e The laws of vortex motion with reference to the action of vortices on each other, by which it seems possible to estimate the circulation or strength of the trailing vortex loop which is generated by a wing in flight.

f The laws of the actions of vortices with reference to their images in solid surfaces combined with the laws, so far as known, concerning the generation of eddies and vortices by friction, especially near sharp edges.

g The concept of a local direction of the wind as due to the effects of all vortices existing in the neighborhood of a wing —such as its own trailing vortices and the influence of neighboring circulations.

h Laws concerning the energy contained in various distributions of vortex motion by which one may estimate favorable arrangements of the trailing vortex systems in terms of the load carried by various parts of the wing span, and from which the drag might be estimated.

i Coefficient of friction and head resistance representing losses of energy which can be added to the losses attributed to the energy of the trailing vortices.

j Experience concerning the explosion of eddies and vortices and the causes and effects of such disturbances.

It is the writer's belief that there are engineers, mathematicians and experimenters in the Society who can give illuminating and interesting statements concerning the subjects mentioned; and that a group of such statements assembled in the form of a discussion would constitute almost a complete and classical theory of the action of wings in steady flight. This paper therefore outlines in a preliminary way the bearing of these various theories and indicates their approximate exactitude.

a The Vortex Theory of Lift. It is not difficult to believe that a component of circulation exists around a wing in flight. If it is granted that the wing carries any load at all, as wings evidently do, there is certainly a difference of air pressure between the lower and the upper surface. Consequently there are accelerations in the neighboring fluid from the under surface around in various circuits to the top surface; corresponding to the fall in pressure from one surface to the other. The quiet or still air into which a wing advances, experiencing these accelerations, must accumulate an upward velocity in front of the wing, and disturbances of a similar nature evidently must occur not only in front of the wing but also to the right hand and to the left hand. Since an upward motion in one region involves a downward motion in another, there must be a downward motion in the rear of the wing. This is a sort of circulation up in front and down behind; and consequently to the rear above and in a forward direction below.

In practice such motions can sometimes be seen in the form of little jerks or jumps of a fluid in the neighborhood of a model wing passing through it. It is not difficult to believe that this disturbance around a wing is rather similar in arrangement to the distribution of velocity around a vortex or group of vortices —their axes parallel to the span of the wing, and perpendicular to the direction of advance. The intensity of motion is very likely greatest near the seat of the disturbance.

According to mathematical theory the lifting force would be in proportion to the strength of the vortex and to its rate of advance, just as the lifting force on a wire in the armature of an electric motor is in proportion to the strength of the current and to the intensity of the magnetic flux from the pole pieces. A formula is given in the Encyclopedia Britannica for the theoretical action of a vortex which surrounds a circular rod which is projected sideways. A force develops perpendicular to the axis of the rod and vortex and at right angles to the motion of advance. This is very similar to the lift of a wing in flight.

Practical examples, however, suitable for mathematical analysis seem to be very rare, nevertheless the writer found one case which seemed to be reasonably free from objectionable complications. This was a wing tested by Eiffel (Eiffel No. 8, at 9 deg. center section). From the measured pressures in this case the probable approximate velocities of the air near the wing surface were estimated, using Bernoulli's theorem. From these velocities a calculation was made of the circulation around the wing, which is the line integral of the tangential component of the velocity vector in a circuit around the wing. The result agrees with the theoretical formula for lift, or $L = \rho Vml$, in which L = force perpendicular to advance; ρ = density of air; V = velocity of advance; m = circulation of the vortex; and l = length taken along vortex axis. It would be interesting to have more measurements of the circulation around wings.

b Theory of Initial Motion Around Wings. It is very evident that no circulation exists around a wing when it is standing still in quiet air on the ground. Mathematical theory further declares that circulation cannot be expected to develop immediately at the beginning of the advance. In the first instant of motion conditions are supposed to be very much as they would be in a perfect fluid. The amount of circulation if zero at the start would be zero immediately afterward. For example, imagine, for simplicity's sake, an inclined plane moving from the position AA' to BB' in Fig. 1, starting suddenly from rest. The

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volume equivalent to the space AA'-BB' can be expected to be displaced and to go around the edges in such a manner that there is no net circulation around the section. Very soon after this beginning of motion, however, in the case of a real wing suddenly started in a real fluid, a very violent eddy or vortex is left behind at $A'B'$. When the wing has advanced to a further position CC' the conditions are as sketched in perspective in Fig. 2. There is a vortex loop stretching rearward from near the wing tips and joined together by the eddy generated at the starting point.

c Vortex Theory of Shape. Suppose that the axes of a number of equal-sized vortices are arranged as the black circles in Fig. 3. Then the direction of motion in the fluid due to their combined action in almost exactly[1] in the direction indicated by the full-line arrows. Suppose that a certain motion of translation is added to this particular arrangement of vortex motion. Then the resultant velocity of total result may be in the directions indicated by the dotted arrows. This particular kind of fluid motion corresponds to a certain velocity of motion added to a certain arrangement of vortices.

Now it is a fact that the shape of the curved line of circles shown in the diagram is, as nearly as may be judged, the effective shape of a cross-section of a certain real wing (Eiffel No. 8 at 9 deg.), deducting an allowance for the thickness of the section. Also it is a fact that the spacing of the circles indicates the actual distribution of lifting force experienced by that wing between the front and the rear of the wing section. Also the component of horizontal velocity added to produce the dotted arrows is the velocity used in the published tests of this real wing, and the vortex strength used in preparing the diagram agrees with the vortex theory of lift and the estimated circulation around the

FIG. 1 DIAGRAM ILLUSTRATING THEORY OF INITIAL MOTION AROUND WINGS

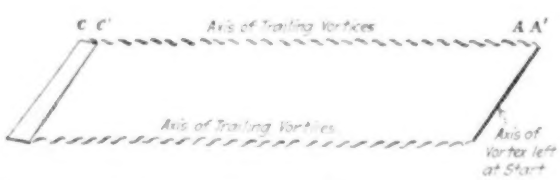

FIG. 2 DIAGRAM FURTHER ILLUSTRATING THEORY OF INITIAL MOTION AROUND WINGS

wing mentioned. Altogether, it is evident from these figures that there is a close connection between the factors of lift, distribution of lift, strength of circulation and distribution of fluid motion and shape.

d Hydrodynamic-Electromagnetic Analogy. Diagrams like Fig. 3 are easily obtained, not by mathematical calculation but by arrangements of electric currents and magnetic fields representing vortices and velocities, choosing any desired amount of flux to represent a standard velocity.

e Action of Vortices With Reference to Each Other. The Encyclopedia Britannica gives formulæ for the action of groups of parallel columnar vortices upon each other, in terms of the strength of these vortices and their distance apart. It is interesting to estimate the strength of the trailing vortices from a biplane by observing their actions on each other. The pairs from the right-hand wing tips are of one kind or direction and revolve around each other in approximate circles. Those from the left-hand tips also revolve around each other, but in the reverse direction from the first-mentioned pair. Very careful experiment would be required to detect any error in the vortex theory of flight in terms of the action of these pairs of trailing vortices.

f Action on Vortices With Reference to Their Images. Many peculiarities of fluid motion are roughly explainable in terms of the action of eddies as if under the influence of their images in solid surfaces. For example, there is a remarkable difference in the circumstances surrounding the eddies formed at B and B' in Fig 1 on the upper surface of the plane. One at the rear B' should tend to roll off if considered as under the influence of its image. Conversely, the one at A should tend to remain with the plane.

g Influence of the Local Wind. Vortices, although regarded as having their axes in some particular location, are usually con-

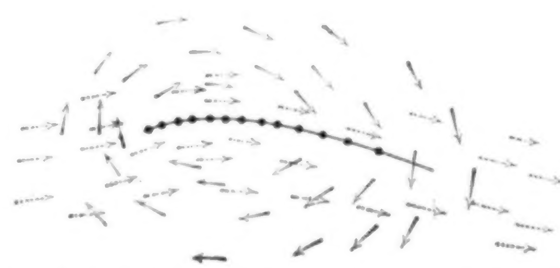

FIG. 3 DIAGRAM ILLUSTRATING HYDRODYNAMIC-ELECTROMAGNETIC THEORY

sidered as having an influence through the fluid in which they exist, just as the magnetic effect of a direct current is considered as having an effect at remote distances. It is interesting to calculate the effect of this influence on a wing of short span. Such a wing in horizontal flight does not act as if encountering a horizontal onrush of the atmosphere. It acts as if there were a downward component of motion in the air around the wing, of very much the same amount that might be calculated from the strength of its own trailing vortices. This is manifest in a relatively poor lift, as if something were reducing the angle of attack, and in a greater resistance as if climbing up through a descending wind.

h Laws of Energy Content in Trailing Vortex. Mathematically it would appear to be as easy to calculate the energy of vortex-motion lift in the wake of an airplane as it is to calculate electrical self-inductance. The arrangement of trailing vortices behind an airplane evidently depends considerably on the distribution of the loading along the wing span, because a wing can terminate in effect considerably short of the actual tip by an easing up of the lift. Calculations concerning the best arrangements would be interesting. The writer has made some approximate computations by assuming the trailing vortices to be a group of parallel columnar vortices: a sort of vortex sheet constituting the wake of the wing. This method of calculation applied to a monoplane gives the usual values of the lift-drag ratio when friction is taken into account.

i Friction and Head Resistance. In a practical way friction is a very large item and it would be very interesting to have separate tests for the friction losses of wings. For example, tests might be made of the resistance of a hoop or endless ring having the cross-section of a good wing.

j Explosion of Eddies. Frequently the low pressure at the center of a vortex or eddy in real air appears to be penetrated by a rush of air along the axis. Knowledge about this, especially with reference to the effect, cause and control of such disturbances in the wake of wings, would be interesting.

DISCUSSION

JOHN R. FREEMAN[1] (written). The writer is hardly competent to discuss Mr. Durfee's paper in the language and symbols of mathematics, but a possible line of investigation of these phenomena occurs to him which may perhaps be useful.

[1] "Almost exactly," because the diagram contains an almost imperceptible allowance for the termination of the sustaining vortices within the lengths of the wing span and for the influence of their rearward extensions as trailing vortices.

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About ten years ago when members of our Society were guests at a meeting in England of the Institute of Mechanical Engineers, the eminent mathematician, Dr. Hele-Shaw, presented an illustrated discussion on stream-line problems in air currents relating to airplanes, in which he showed the disturbing effect upon the streamline of models designed to represent various forms of wings. The fluid in that case was a liquid and the stream lines were represented by ingeniously colored liquid filaments. The investigation was along lines of previous investigations of the distribution of velocities in flowing liquids containing colored liquid threads which showed the eddy currents caused by such obstructions as bridge piers.

At that time it seemed to the writer that the difference in compressibility of air and water, and also the difference in inertia effect, impaired the analogy, and on further thought he laid out a line of experiments for tracing the motion of liquids around obstructions in channels by a combination of methods borrowed from the ultra-microscope and the moving-picture machine, although he has never found time to carry out the experiments. This method seems admirably adapted to experiments on air currents in connection with airplanes.

The method in brief is to make an optical cross-section in any desired plane by means of a thin, broad beam of intense light put into appropriate shape and parallel rays by proper condensing lenses and an optical slit, analogous to that used with the ultramicroscope. By means of dust particles of proper density introduced in the air current, one can render visible the direction and velocity of the currents set up somewhat as he sees the air currents in his living rooms made evident by a sunbeam acting upon the suspended dust particles.

The narrow slit of light reveals only the motions in one plane and simplifies the observation by rendering the particles visible only while traveling in this optical plane.

In the case of the airplane, these motions would mostly be too rapid for the eye to follow, but within limits it is possible to observe them and to record them by a motion-picture apparatus which can be so constructed as to make 30 or 50 exposures per second instead of the customary 16. It is indeed possible to obtain exposures of much shorter frequency by means analogous to the shutter-testing device developed in Dr. Mees' Research Laboratory at Kodak Park, in which a rapidly revolving polygon of mirrors serves to catch and record the fleeting image. Also there have been devised and patented means of revolving polygonal prisms of glass, so adjusted that their reaction holds the image approximately stationary on the screen or film for the fraction of a second.

Such a series of photographs recorded in a short reel of film can be rotated for purposes of study at a much slower speed than that at which they were taken.

By these means the writer believes the actual pathway of the particles of air as they pass either wing plane or propeller can be made evident and precisely recorded at velocities far higher than can be observed in any other known way, and a series of optical sections, analogous to those of the ultra-microscope or the sunbeam, will simplify the hopeless complexity of a dense mass of particles traveling in various directions.

Edward P. Warner[1] (written). It is manifest that any considerable development of the theory of wing action beyond the point already reached must be conditional on the use of new and more powerful and logical methods of attack. In most of the work so far done, whether by the simple assumption of plane impact and reflection or by such more elaborate methods as that of Kirchhoff and Helmholtz, the continuity of the air has been ignored, and the results have consequently been far from the truth.

The work of Lanchester, Kutta, and others on a vortex theory of sustentation seems to offer the most promising path to an analysis of wing action which shall be of real practical use. It leads to the only method which takes due account of the fact that there can be no actual acquisition of downward momentum by the air as a whole, since the center of gravity of the atmosphere cannot shift, and any downward motion imparted to the air in the neighborhood of the wing must be counterbalanced by an equal upward motion imparted to an equal mass at some other point.

Promising as the vortex theory is, however, it should not be overrated. There are many factors in the action of wings for which it does not appear to account, and the mathematical weapons are not at hand for applying it, except in the simplest cases. The electromagnetic analogy proposed by Mr. Durfee is very interesting, but it must be handled with care, particularly in connection with thick wings, where the air flow changes from stream-line to turbulent types and back again with the greatest suddenness and in response to the minutest alterations of wing form or conditions of operation. It is doubtful if this analogy could be extended to any cases beyond those of the flat plate and the simplest forms of thin, cambered sections.

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George De Bothezat[1] (written). The statement "*a*" of Mr. Durfee's paper constitutes in reality the well-known "Kutta theorem," discussed by Kutta himself (*Illustrirte Aeronautische Mitteilungen*, 1902; Sitzungsberichte der Königlichen Bayerischen Akademie der Wissenschaften, 1910 and 1911), by Joukowski (*Aérodynamique*, Paris, 1916) and by Dr. de Bothezat (Report No. 28, Note I, from Fourth Annual Report, National Advisory Committee for Aeronautics).

The statement "*c*" was first made by Lord Kelvin with reference to an example actually classical (the so-called atmosphere around a system of two rectilinear and parallel vortices rotating in inverse sense).

The statement "*d*" of the hydrodynamic-electromagnetic analogy is well known. But the suggestion to study the flow around an airfoil by this method is of interest, and such experiments conducted in a suitable manner could bring out valuable results.

A solution of the question proposed in statement "*e*" is directly obtained by the successive application of the Kutta theorem, Lord Kelvin theorem on the constancy of circulation, and the Stokes theorem connecting circulation with vortex intensity. (See Report No. 28 of the Fourth Annual.)

The statement "*g*" is not quite clear; if local wind means only the instantaneous value of the fluid velocity at a given point around the airfoil, it is only a regular conception.

The statements "*h*" and "*i*" demand very careful consideration, because it seems that in the case of hydrodynamic phenomena some special conditions may occur which we do not meet in electromagnetic phenomena.

F. W. Caldwell[2] (written). This paper is very timely, particularly in view of the growing tendency among aeronautical engineers to regard the classical coefficients K_x and K_y as inadequate.

It has been almost universally the practice to write $L = \frac{\rho}{g} \times K_y S V^2$ and $D = \frac{\rho}{g} K_x S V^2$, where L is the lift, D the drag, S the area of the supporting surface, V the velocity of advance, ρ the density of the air in weight units, and g the acceleration due to gravity, hence $\frac{\rho}{g} =$ density of the air in slugs.

It is well known as the result of experience that the values of K_y and K_x vary somewhat with velocity and also with the size of the surface under consideration. If l represents one of the linear dimensions of the surface it is assumed that the values of K_y and K_x are functions of the product Vl. This is known as the scaling effect.

Information on the scaling effect is very meager. In the case of propeller sections we have been forced to make use of characteristics obtained at a speed of 30 miles per hour and apply them to conditions where the speed obtained is as great as

(*Continued on page* 787)

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Fatigue Phenomena in Metals

A Report Summarizing the Available Facts and Theories Relating to Fatigue Failure and a Discussion of Some of the Unsolved Problems

METAL parts of machines, such as springs, shafts, crank-pins and axles, occasionally fail suddenly while only subjected to conditions of ordinary service. Not only does failure occur suddenly, but the part about to fail shows no ordinary evidence of weakness. The broken parts when examined are seen to be broken off short, and without general distortion, even though the material may show high ductility in ordinary tests. Such failures are found only in parts subjected to stress repeated many times—to "vibration," as it is sometimes stated—and the phenomena which are involved in the final failure of metal through oft-repeated loading are known as "fatigue" phenomena of metals.

The phenomena of fatigue failure have recently given rise to some perplexing problems in connection with the design and service of airplane-engine crankshafts, the hulls of steel ships, axles and shafts in railway cars, motor cars and trucks, and other machine parts. The question whether structural parts subjected to repeated stress are in danger of fatigue failure has been discussed at considerable length. The danger of fatigue failure seems to be an unimportant factor in determining the safety of structural parts, with the possible exception of parts subjected to reversal of stress. The reason for this is probably found in the relatively small number of loadings which most structures are called upon to withstand, and in the fact that most of the loadings are below the maximum working value. On the other hand, the danger of fatigue failure is a major factor in determining the safety of many machine parts.

The problem of fatigue of metals engaged the attention of engineers seventy years ago, in connection with car axles and members of iron railway bridges. It was early recognized that high stress tends to cause, or at least to hasten, fatigue failure, and about 1860 Wöhler's famous investigations[1] were undertaken to determine the relation between intensity of fiber stress and the ability of materials to resist fatigue under repeated stress. Wöhler's tests occupied some eleven years, and remain to this day the most thorough tests on record. Wöhler investigated metals under direct tension, under bending, and under torsion (shear). For some of his tests the stress varied from zero to a maximum, and for others the stress was reversed. The results of Wöhler's tests may be summarized as follows:

1. A machine part or structural member may be ruptured by the repeated application of a load which produces a computed fiber stress less than the ultimate strength of the material as determined by a static test
2. The greater the range of stress, the lower the limiting fiber stress to insure against rupture after a very large number of repetitions
3. To insure against rupture after a very large number of repetitions of loading causing complete reversal of stress, the limiting fiber stress is but little greater than one-half the limiting fiber stress for a very large number of repetitions of stress varying from zero to a maximum.

Following Wöhler the famous Bauschinger[2] published a series of conclusions on fatigue, and various other investigators, notably Gerber,[3] and Weyrauch and Launhardt,[4] gave early interpretations of the experimental results of Wöhler and Bauschinger.

In these earlier experiments several facts seem noteworthy. The prime object of the investigators was to deduce laws of fatigue for railway bridges and car axles. The problem of fatigue in high-speed machine parts had not then appeared. These investigators carried their tests far enough to cover the number of repetitions required by the structures of their day and assumed that having done so they had established an endurance limit. Reading their conclusions carefully, the statement does not seem to be made that material which passed their tests would stand an *infinite* number of repetitions. The term generally used is "indefinite" or "very large," and the number corresponding is from ten to fifty millions. For the problem which they investigated their tests seem to give safe guides for practice, but today, with the advent of modern high-speed machinery, some parts of which must be as light as possible, and the extension of the fatigue problem to such members as the cranks and the connecting rods of gas engines and the shafts of steam turbines, the number of repetitions of stress which a machine member may be called upon to undergo is very much increased. This fact is illustrated by Table 1, which gives a statement of the approximate service required from various structural and machine members.

Investigations have been made in recent years by Howard,[5] Stanton,[6,7,8] Basquin,[9] Smith,[10] Eden, Rose and Cunningham,[11] Kommers,[12] Mason,[13] Moore and Seely,[14] and others. The efforts of these investigators have been directed toward the study of modern materials, refinements in methods of testing, and interpretation of results. The limits of actual tests have not been extended to modern requirements, and the problem still remains of obtaining test data for much longer endurance of fatigue than was contemplated by Wöhler. Under the most favorable conditions conceivable such data will be obtained very slowly, and meanwhile there must be faced the problem of determining safe stresses for very large numbers of repetitions by extrapolation from previous test results.

TABLE 1 APPROXIMATE SERVICE REQUIRED OF VARIOUS MEMBERS OF STRUCTURES AND MACHINES SUBJECTED TO REPEATED STRESS

Part of structure or machine	Approximate number of repetitions of stress in the "lifetime" of the structure or machine
Railroad bridge, chord members	2,000,000
Elevated-railroad structure, floor beams	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, car wheel loads	15,000,000
Airplane-engine crankshaft	18,000,000
Car axles	50,000,000
Automobile-engine crankshaft	120,000,000
Lineshafting in shops	360,000,000
Steam engine, piston rods, connecting rods and crankshafts	1,000,000,000
Steam-turbine shafts, bending stresses	15,000,000,000

Machines for Testing Fatigue Strength

Fatigue tests cannot readily be carried out with ordinary "static" testing machines. It is, of course, possible to repeat loadings on a test specimen in such a machine, but the process is very slow. Such a machine equipped with an ingenious auto-

A progress report of the Committee on Fatigue Phenomena in Metals, which is acting under the joint auspices of the Engineering Foundation and the Division of Engineering of the National Research Council. The society contributes toward a portion of the cost of this research and the report is presented to the membership through the Research Committee of the A. S. M. E., Prof. Arthur M. Greene, Jr., *Chairman*. The personnel of the Committee on Fatigue Phenomena is as follows:

H. F. Moore, *Chairman*, Research Professor of Engineering Materials, Engineering Experiment Station, University of Illnois, Urbana, Ill.

O. H. Basquin, Professor of Applied Mechanics, Northwestern University, Evanston, Ill.

Zay Jeffries, Director of Research, Lynite Laboratories, Aluminum Castings Co., Cleveland, Ohio.

T. R. Lawson, Professor of Rational and Technical Mechanics, Rensselaer Polytechnic Institute, Troy, N. Y.

J. H. Nelson, Engineer of Tests, Wyman-Gordon Co., Worcester, Mass.

W. E. Ruder, Research Department, General Electric Co., Schenectady, N. Y.

H. L. Whittemore, Chief, Section of Metal Testing, U. S. Bureau of Standards, Washington, D. C.

[1] For this and following references see page 738.

matic arrangement for applying and releasing load was used by Van Ornum[15] in fatigue tests of concrete in compression, but the time required for even a hundred thousand cycles of stress was very great.

A very simple repeated-stress testing machine acts by the application and removal of a weight to the end of the long arm of a simple or compound lever, the specimen carrying load at the short arm. Such a machine was used by Berry[16] in fatigue tests of concrete in compression. In a machine of this type the load must be applied slowly, else there will be inertia forces set up by the impact of the weight as it is let into place.

A common type of repeated-stress testing machine is one in which a calibrated set of springs resist the tensile, compressive, flexural, or torsional stress set up in the specimen, and the deformation of the calibrated set of springs gives a measure of the force or moment acting on the specimen. Fig. 1 diagrammatically illustrates this type of machine which was used by Wöhler and has since been used by many other experimenters. The Upton-Lewis machine is of this type and extensive use was made of it in torsion tests carried on by McAdam.[17] This type of machine permits a fairly high rate of repetition of cycles of stress, and machines which have been run at 1000 repetitions per minute have given results apparently trustworthy.

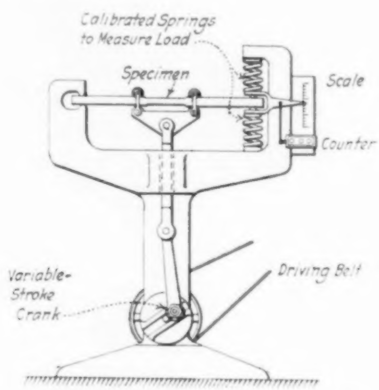

Fig. 1 A Type of Repeated-Stress Testing Machine

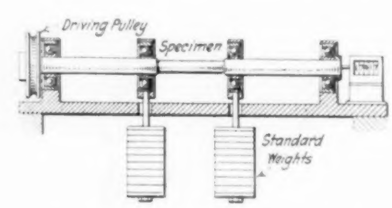

Fig. 2 Type of Machine for Determining Reverse Bending Stresses

The most common type of machine for reversed bending stresses uses a circular specimen acting as a rotating beam. This type was used by Wöhler, and also by many later investigators. Fig. 2 illustrates such a machine. The specimen is in the form of a bar of circular section, to which bending stress is applied by weights. The specimen is rotated by means of a pulley. At any instant the outer fibers are subjected to a stress varying from tension on one side to compression on the other, and the fiber stress at any point passes through a cycle of reversed stress during each revolution. As shown, the specimen is loaded at two symmetrical points of the span, and between these two points the extreme fiber stress is constant for each element along the bar. This type of machine permits high speed of reversal of stress, speeds up to 2000 r.p.m. having been successfully used.

British experimenters have used repeated-stress testing machines in which varying stress was applied to a specimen by means of the inertia of reciprocating parts. Fig. 3 shows such a machine, which can be used at high speeds. However, the speed must be very closely controlled, as the inertia forces vary with the square of the speed. Moreover, friction on the guides causes some slight uncertainty as to the magnitude of stress set up at each stroke of the crank.

A repeated-stress testing machine depending on centrifugal force to produce cycles of stress is shown in Fig. 4. It is evident that as the eccentric weights revolve the specimen will be placed alternately in tension and in compression. This machine has been used by J. H. Smith.[18] Its characteristics are much like those of the inertia type; in fact, it is a special form of inertia machine.

A type of machine used by Arnold and later by other experimenters is shown in Fig. 5. In this machine a specimen is repeatedly given a certain deflection. Usually this deflection is sufficiently large to stress the material well beyond the yield point, and no very definite stress can be computed. This machine is used mainly for short-time tests.

Another short-time-test machine uses the repeated impact of a small hammer. The claim is made that impact loading emphasizes local flaws better than a load which is more gradually applied, and that thus it *indirectly* gives a better index of fatigue strength. Data, however, are lacking to prove or disprove this claim.

Various repeated-stress testing machines have been constructed in which the cycles of stress were set up by the action of an electromagnet energized by alternating current. Usually the stress was measured either by the deflection of a spring or by the deformation of a standard test bar attached to the specimen. The speed of such a machine, however, is usually so high that there seems to be some uncertainty as to whether the successive waves of stress pass through the specimen without interference.

While the microscope can hardly be classified as a testing machine, it has, nevertheless, been of such vital importance in studying fatigue phenomena that it may well be mentioned in this place. Space will not permit of a detailed description of the methods employed in the microscopic examination of metals, but the process involves polishing a small area of the metal, etching the surface with some reagent to bring out the lines of the crystalline structure and examining and photographing the surface through a microscope, the surface of the metal being illuminated by means of a reflected light.

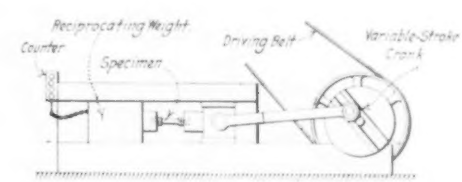

Fig. 3 British Form of Repeated-Stress Testing Machine

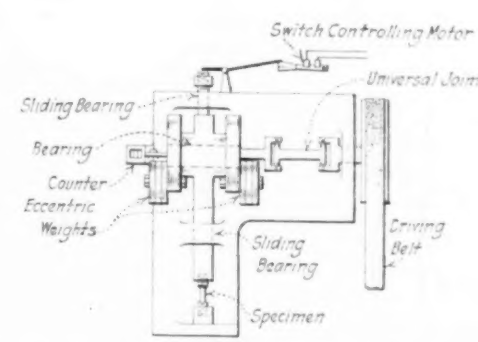

Fig. 4 Special Form of Repeated-Stress Testing Machine

The Phenomena of Fatigue Failure

A fatigue failure of a metal, whether it occurs in a test speci-

men or in a machine part, is characterized by suddenness, lack of warning, apparent brittleness of material, and, in many cases, a fracture with a crystalline appearance over a part of its surface.

This crystalline appearance led to the old theory that under repeated stress metal "crystallized," changing from a ductile "fibrous" structure to a brittle "crystalline" one. This theory, however, has been quite thoroughly demolished as a result of study of the structure of steel under the microscope. As revealed by the microscope the structure of all metals used for structures and machines is crystalline, any "fibrous" structure being caused by inclusions of non-metallic impurities (for example, slag in wrought iron). Microscopic examination of metals under stress shows no change of the general scheme of internal structure, but under sufficiently heavy stress there appears gradual breakdown of the crystals in the structure.

When a ductile metal is deformed cold, the first deformation occurs in the particular grains which either take the most stress or have the lowest elastic limit. Deformation takes place by the slipping of one portion of the grain with reference to other portions. This slipping is shown by the appearance of lines called "slip bands" or "slip lines" extending across crystals and indicating planes of cleavage, as shown in Fig. 6. As the load is increased deformation proceeds and other slip bands are formed, the law being that the most easily deformable grains first show slip bands. Gradually the most favorable planes of slip are exhausted, and further slippage can take place only with the addition of more load.

The failure in ductile metals subjected to repeated stress takes place with substantially no general deformation There is, however, considerable local deformation over microscopic areas, evidenced by the appearance of many slip bands on a polished surface of the metal after the application of repeated stress. These slip bands appear after a small number of reversals of stress with relatively large loads, and may not appear at all with slight loads. The slip bands may first appear either in the interior of a grain or at the grain boundary. As the number of applications of stress increases more slip bands appear, and those first appearing usually lengthen and widen. Under the microscope and with normal illumination the general surface becomes blacker as the number and width of the slip bands increase. In ductile metals fatigue failure is almost exclusively through the grains themselves rather than at the grain boundaries, and the first slip bands to appear do not necessarily form a part of the final path of rupture. Failure seems to take place by the uniting of slip bands into cracks. When the first grain develops a crack extending across its entire width, added stress promotes the extension of this crack into adjacent grains on both sides, although the orientations of these grains may be and usually are such that the crack must extend itself at an angle to that in the initial grain. The general tendency is for these slip bands to follow the lines of cleavage of the particular grain in which they occur. Often incipient fracture is found in many grains adjacent to the final path of rupture, indicating that had rupture not taken place where it did, it would have soon taken place in some other adjacent part.

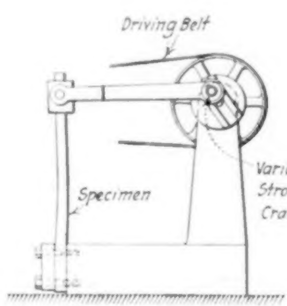

FIG. 5 SHORT-TIME REPEATED-STRESS TESTING MACHINE

Such observations by means of the microscope indicate that *localized deformation* is the primary cause of fatigue failure in ductile metals, but it does not necessarily follow that the formation of one slip band under repeated stress will indicate eventual fracture if the loading is continued; one grain may appear to have a greatly reduced elastic limit because of internal strains or peculiarly unfavorable orientation. It is not certain that there is a limiting load below which fatigue failure will never take place.

Materials classified as brittle have very little permanent deformation under static stress, and under repeated stress the progressive fracture of brittle material might take place, not by slipping within crystals, but by tensile fracture of crystals. There has been practically no study made of the fracture of brittle materials under repeated stress, and it would be instructive to have tests carried out on brittle amorphous materials such as fused silica and on brittle crystalline materials like marble or tungsten. It is gradually being recognized that the breaking load of a specimen is a complex matter, and depends, among other things, on the time of application of the load. Mere duration of static loading, however, does not have an effect at all comparable with repetition of loading in reducing the breaking load. It seems evident that the distribution of stress in some brittle materials is very much less uniform than in ductile materials, and that fractures in brittle materials start on areas of high stress, whereas in ductile materials the high stresses are relieved by local yielding. A more complete understanding of the mechanism of rupture in brittle materials would doubtless be of great value.

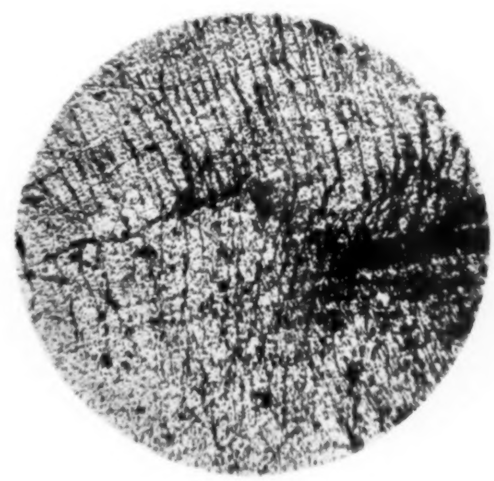

FIG. 6 APPEARANCE OF "SLIP BANDS" INDICATING PLANES OF CLEAVAGE

When the action of metal under repeated stress is considered from the viewpoint of the internal strains and accompanying stresses in the material, a radical difference is seen in the behavior of material under static load and under repeated load. In a general way we may consider any structural or machine part as subjected to static conditions if the load on it is applied gradually and is not repeated more than a few hundred times; the part may be considered as subjected to fatigue if the load on it is applied, say, one hundred thousand times or more; and for intermediate conditions of loading the phenomena characteristic of both kinds of loading would be present.

We must look upon steel as filled with a multitude of minute flaws. These flaws are developed in the solidification of the material. In static testing, steel under stress of about half its ultimate strength passes into a semi-plastic condition, in which there is a gradual flow of the material. Under such conditions the small flaws have almost no effect upon the flow or upon the static strength. When steel is loaded to moderate stresses the yielding is almost entirely elastic, but in general a small portion of it is inelastic, energy being taken up by the steel itself. If the specimen can be loaded a great number of times without heat loss its temperature will increase. If it is set vibrating in a chamber free from air it will stop vibrating in a short time, due to the absorp-

tion of energy. In such cases the stress-strain curve appears to be straight and the curve for the removal of the load may be practically identical with that for the application of load, but still these other effects show loss of energy in the steel itself.

This loss of energy is doubtless due to small displacements at these flaws, which are not reversible. Under alternate loadings these displacements are made back and forth. Energy is continuously being absorbed in the location of these small flaws, and it is perfectly natural that they should increase in size. We must look upon these extensions of the flaws as occurring in a great many parts of the steel. If the stresses are small the increase in size of these flaws is practically negligible, but if the stresses are larger the increase is rapid, and later on in the history of the piece under test, very rapid, and finally the strength of the piece is terminated when a sufficient number of these flaws have connected so as to form an area of very great weakness.

For static loads all the above is of little consequence with a ductile metal; but it is of consequence in the case of a brittle metal like cast iron, which has a remarkably low strength in tension in comparison with its compressive strength. Ductile metals may be considered as having a very high value for cohesion with a rather low coefficient of friction—or whatever corresponds to that—so that these metals begin to slide on diagonal planes without actual fracture under high local stress.

When a ductile material is loaded it may be subjected to stresses whose average values for small areas are not very different for parts that are a tenth of an inch apart; but there is a multitude of tiny spots whose fiber stresses are 2, 3, 4 or 10 times the average value.[23, 24, 25] This holds so long as elastic conditions obtain. As the applied stress increases some of these stresses increase in like ratio, but not in like increments. At moderate applied stresses these special stresses reach inelastic conditions and slipping occurs. If the average stress is now entirely removed, we may assume that the unloading takes place in a similar manner. The small spots unload first in an elastic manner, but at a different rate than the remainder of the material. They will unload approximately at the same rates as they used in taking stress, namely, 2, 3, 4 or 10 times the normal rate. For the unloading they have about twice the range of stress that they had in the loading before inelastic action is set up. Some of them will reach the opposite limit and slip part way back again, while some of them may not be subject to this return slip of inelastic action, but will retain in the unloaded state a stress distribution of the opposite kind. Either of these actions will give rise to hysteresis and to slight change of dimensions, usually, however, too small to be detected.

In all of the foregoing the main parts of the material have not been subjected to stresses which give inelastic action. If the loading is repeated without reversal, the spots that slipped on the first unloading will be subjected to further slipping both on loading and on unloading, but the areas that suffered no slipping on the first unloading should show no further inelastic action unless the loading is reversed. If the loading is reversed, however, all the particles that slipped in the first loading will slip on the reverse loading, so that with repetition a larger number of spots undergo this slipping action than is the case with loading which is not reversed. This explains the shorter life under reversed stress than under repeated stresses in one direction only.

If the fractured surface of a "rotating beam" specimen made of ductile metal and broken by repeated stress is examined, it is usually seen to be made up of two parts: (1) near the extreme fibers there is a dark surface with a dull, lusterless appearance, while (2) the remainder of the surface has a bright crystalline fracture. If these are examined more carefully it is found that their principal difference is in the size of the small flat surfaces that constitute the fracture. The center portion of the area has comparatively large surfaces, giving a crystalline effect, while the dull gray portion has very small surfaces of fracture.

An explanation of this is that the flaws in the outer portion of the surface have connected to form an annulus, whose rugged face is roughly at right angles to the axis of rotation. This has doubtless occurred slowly, and has started from many centers, thus giving the rough face. After this slow growth of flaws into an annular fracture has been accomplished the specimen has become very weak and the stresses have become so large at the fracture that they suddenly tear the metal in two on the natural surfaces of cleavage of the crystal grains.

The center portion of this fractured surface does not differ from the crystalline surface at the bottom of a cup in an ordinary static tension fracture, except that the crystalline surfaces are somewhat larger. This is to be explained by the fact that in an ordinary tensile test the material at the fracture has elongated something like 100 per cent, so that the crystal grains have become of smaller cross-section and will naturally show smaller facets on fracture, whereas, in a fracture of the endurance specimen, the material has had no chance to elongate and the crystalline grains have their normal size, which will be shown in fracture. It is not the crystalline portion of the broken specimen which has failed primarily by repeated stress, but the dull portion. In the crystalline part of the fatigue fracture and in the crystalline part of the static tension fracture the failure seems to be of the same nature, namely, a failure in cohesion.

In considering the phenomena of fatigue failure it may be well to call attention to the fact that there is an intermediate type of failure of ductile material in which both plastic action and the development and spread of microscopic flaws are present. Such failures sometimes occur in staybolts, boiler sheets between rivet holes, and other parts occasionally subjected to very severe local distortion.

Localized Stresses Under Static Loading and Under Impact Loading

When a machine member or structural part is loaded gradually a state of strain and accompanying stress is set up throughout it. In a general way the distribution of stress is similar to that given by the theory of elastic action which serves as a basis of our formulæ for computing stress and strain. There are, however, many deviations from this distribution due to non-homogeneity of the material and to irregularities in outline such as projecting corners, scratches and tool marks. When load is applied the general behavior of the piece as indicated by careful measurements of stretch, compression, twist, or flexure conforms to that required by the common theory of elastic action, but there are doubtless many localized strains which cannot be detected, even by the use of delicate micrometer measurements. It is to be recalled that in measuring strains it is necessary to use a gage line of considerable length, with the result that the observed strain is an average value along a relatively long line. The localized stresses, corresponding to these undetected localized strains, are not of any great importance under static load. When the load is increased to such an extent that a considerable portion of the piece is stressed beyond the elastic limit, the distortion of the piece increases abnormally and the piece may be considered to have reached its yield point. After this limit is passed the distribution of stress is much modified, and for parts made of ductile material the abnormal distortion at the yield point usually gives warning of structural damage before complete failure occurs.

Under impact loading, which is merely loading applied in a very short space of time, the action is somewhat similar to that under static loading, except that ductile material may offer a higher resistance to very rapid fracture than it does to fracture occurring gradually through a period of several minutes. Impact fracture, moreover, may emphasize somewhat the localized stresses set up at places where the structure of the material is non-homogeneous, or at places where there are sharp notches or deep scratches in the surface of the piece. Under slowly applied load there is opportunity for considerable adjustment and equalization of stress after the yield point is passed; under impact load there is probably less equalization on account of the rapidity of the action, and hence the localized stresses are higher and more effective in causing failure. This explanation of the action under impact is given here because repeated stresses also emphasize the effect of high localized stress, though for an entirely different reason.

Tests and Criteria for Fatigue Strength

It was formerly the common opinion that the determination of the elastic limit of a material by means of a static test in a testing machine gave a reliable test for the fatigue-resisting qualities of the material, and that the material could withstand an infinite number of repetitions of stress lower than this elastic limit. Tests at various laboratories, however, have quite thoroughly disproved this idea, and have thrown grave doubts on the reliability of the elastic limit as an index of fatigue strength. The term "elastic limit" has always been rather loosely used, and covers several quite different stresses.[18] The value determined for the elastic limit for any material depends on the sensitiveness of instruments used and the accuracy of plotting results, and the elastic limit as determined by such a test in a testing machine is determined by the average behavior of the material over a considerable length, while the process of fatigue failure may be going on over a section so small that it does not appreciably affect the readings of the measuring instruments used. In several laboratories comparative repeated-stress tests of different materials have shown higher fatigue resistance for the material with the lower elastic limit.[19, 20, 21]

Bauschinger in his classic experiments showed that the elastic limits in tension and compression as determined by ordinary testing-machine tests were variable limits, their value depending on the treatment of the material during fabrication. He called such limits "primitive" elastic limits, and showed that when a specimen is subjected to gradually increasing range of alternating stress there are soon set up two elastic limits in the bar—one in tension and one in compression. He called these limits, which may have values widely different from the "primitive" elastic limit, the "natural" elastic limits, and the range between them the "elastic range." He also showed that a test specimen will stand several million repetitions of this elastic range of stress without failure, and proposed the "natural" elastic limits as indices of the fatigue-resisting strength of the material. J. H. Smith[10] has developed a somewhat simplified process of determining the elastic range. This elastic range seems a more reliable index of fatigue strength than the ordinary "primitive" elastic limit, but the reliability of indices of fatigue strength based on determinations of any elastic limit by testing-machine tests is open to question on account of the possibility that localized fatigue failure may be in progress without affecting the readings of the instruments used in static tests.

Wöhler used as an index of fatigue strength the "endurance limit" of material as determined from a series of fatigue tests with different intensities of stress. He used the method of plotting values of stress (S) against numbers of repetitions required for fracture (N) and determining by eye where this S-N curve became "practically horizontal." Other investigators have plotted values of S against values of $1/N$ or of $(1/N)^n$ and by extending the diagram till it intersected the axis of ordinates have determined an assumed endurance limit for an infinite number of repetitions of stress. Both of these methods involve enormous extrapolation of test data. Moreover, widely different endurance limits can be determined from the same test data by different methods of plotting values.[11] The tendency to irregularity of test results under low stresses makes the decision whether the S-N curve is horizontal or slightly sloping downward one of very considerable uncertainty.

It has been proposed by various experimenters to compare the fatigue-resisting qualities of different metals by short-time tests with stresses well beyond the yield point of the material. Such tests are quickly and easily made. Under such stresses, however, the action of the material is partly a plastic flow. Such tests give good promise of determining fatigue strength and toughness under occasional overload for parts such as staybolts, which in their ordinary service are subjected to rather severe distortion, but it is not at all certain that such tests give a reliable index of resistance of machine parts under ordinary working stresses.[20]

It has been proposed by various laboratories to compare the fatigue strengths of various materials by comparing their life under repetitions or reversals of some standard stress, usually less than the elastic limit of the material as determined by a static test. A somewhat similar standard proposed is to determine the stress which will cause failure under a given number of reversals. Standard stresses proposed for steel are 38,000 lb. per sq. in. (reversal) and 25,000 lb. per sq. in. (reversal). One million reversals has been proposed as a standard "life." These two types of test approach working conditions more closely than do the short-time, high-stress tests described above. However, they determine only one point on a S-N diagram for a material and do not indicate how fatigue endurance changes with change of stress.

A comparative study of fatigue strengths of various materials can be made from a S-N diagram plotted on logarithmic paper. Up to about 1,000,000 repetitions of stress logarithmic S-N diagrams fall quite closely along straight lines, and from the ordinates and slopes of these lines the behavior of materials under various intensities of stress can be studied. Tests may conveniently be made with stresses at about the yield point of the material, at stresses about 20 per cent lower, and at one or two intermediate stresses.

Various other possible tests have been proposed for determining the fatigue-resisting strength of a material, but no test has been proved to be of sufficient reliability to be accepted as a standard. A number of tests, however, seem worthy of experimental study.

The rate of dying out of vibrations in a "tuning fork" specimen of the material has been suggested as a possible index of fatigue strength.[21] It is assumed that the gradual dying out of vibration is due largely to loss of energy spent in inelastic action in the material, and that such inelastic action is a measure of the fatigue weakness of the material. Test data are lacking to determine the value of this test, but it seems worthy of study.

Tests of magnetic permeability have also been proposed to locate internal flaws in the material and thus indicate its relative fatigue strength. The entire subject of the correlation of the magnetic and the mechanical properties of iron and steel is a promising field of investigation.[28]

The rise of temperature under repeated stress has likewise been proposed as a measure of fatigue resistance.[22] Theoretically, if a specimen is subjected to reversed elastic stress no change in temperature should take place, and it has been proposed to determine the endurance limit for metals at that stress which causes the first noticeable rise in temperature after some thousand or more reversals. A practical difficulty in using this test is to secure proper heat insulation for the specimen. This test seems worthy of study, however, especially if employed in an inertia type of testing machine (see Figs. 3 and 4).

The detection of the appearance and growth of "slip lines" in a specimen subjected to repeated stress gives some promise of furnishing a reliable test for fatigue strength. Slip lines appear long before fracture occurs, and if their appearance or the rate of their spread can be shown to be an index of fatigue strength it seems possible that a feasible laboratory test may be devised. The search for slip lines over any considerable area would, however, be very tedious.

Impact tests, usually on notched bars in bending, have been proposed as an index of fatigue strength. The actions under impact failure and under repeated stress are very different, the first giving a sudden break of the entire cross-section of the specimen, and the second a gradually developing fracture. Both failures, however, seem to be affected by localized flaws or irregularities in outline, and though no definite correlation between fatigue strength and strength to resist impact has been established, yet such tests are worthy of study. Repeated-impact tests have also been proposed to determine fatigue strength, but whether such tests have any advantage over short-time tests under non-impact loads is not known.

In all tests to determine fatigue strength it is of the highest importance to secure uniformity of surface finish between the different specimens to be compared. Probably this can best be done by polishing the surface of the specimens where failure is expected.

There is today no short-time test accepted as a standard test

for fatigue strength; but the development of such a test, and the establishment of its reliability, would unquestionably be of very great service to testing engineers.

Localized Stress and Its Influence in Producing Fatigue

The ordinary formulæ and methods of analysis used in computing the fiber stress in a machine part or structural member are based on the assumption that the material is homogeneous throughout, and that the cross-section of the member is either constant or that it changes its dimensions so regularly and gradually that there is no appreciable localized fiber stress at sections of rapid change. For structures and machines of ductile material subjected to not more than a few hundred loadings, such assumptions are reliable, because localized stresses do not appreciably affect the general deformation of a member, nor do they under ordinary working conditions cause trouble before the member has been subjected to some thousand or more repetitions of load. For nearly all parts, however, high localized stresses are present. Internal flaws may cause such localized stresses. This is shown by mathematical analysis of stress in plates with holes in them[23] and by direct experiment on such plates.[24, 25] External irregularities of outline may cause localized stress. Under bending or twisting a member with a sharp reëntrant angle in its outline theoretically develops an infinite stress at the root of the angle,[26] and actually both mathematical analysis and direct experiment show that very high localized stress may be caused by sharp grooves or scratches on the surface of a machine part or structural member.

It has been stated above that for parts subjected to a few loadings localized stresses are not of great significance. The case is quite different, however, for parts subjected to thousands of loadings. High localized stress may cause a crack to start, either directly or by "cold-working" the material where the localized stress exists until the material becomes brittle. This crack forms an extension of the discontinuity of the material which caused it, and under repeated stress tends to spread still more rapidly. This tendency is illustrated by the action of a piece of plate glass in which a crack has started. In most cases under any repetition of load the crack spreads, and will cause final fracture of the glass. A fatigue failure under repeated stress is a progressive failure. This spreading of cracks to cause failure explains why under fatigue even ductile materials snap short off. Failure does not involve plastic flow of considerable masses of metal, but only of microscopic masses near the crack, and final fracture comes suddenly just as if the member were cut half off by means of a saw cut and then bent. The importance of avoiding localized high stress in members subjected to repeated stress can hardly be overemphasized. Homogeneity of internal structure, smoothness of external surface, and avoidance of sudden changes of cross-section may be more important in the construction of machine parts subjected to repeated stress than is high static strength of material.

Shoulders of crankshafts and of axles, keyways in shafts, screw threads, and rivet holes are examples of locations where high localized stress is liable to occur.

Relation Between Microscopic Structure and Fatigue

A very large field of investigation and one in which very little systematic work has been done is the study by means of the microscope of fatigue failures in various characteristic structures of metals, especially steels. The following paragraphs are given as a summary of the theory held by present-day metallographists of the relation of microstructure of metal to its fatigue strength. Many of the details of this theory, however, lack adequate experimental verification.

Annealed steel consisting of ferrite (pure iron) and cementite (iron carbide, Fe_3C) seems to increase in resistance to fatigue with the increase in carbon content, especially when the cementite is present in the form of plates as in lamellar pearlite and as long as the cementite does not surround the grains of pearlite.[27] When the cementite is spheroidized, the elastic limit is greatly decreased and probably the resistance to fatigue is also decreased. As a structural material, therefore, a steel with considerable carbon in the form of spherical globules of iron carbide would have practically no advantages over wrought iron. When, however, the iron carbide is in plates it seems to have a marked effect in raising the elastic limit, and probably increases the resistance to fatigue. We would also expect that complete and large networks of ferrite would lower fatigue resistance.

The same arguments regarding grain size of single constituent metals hold to a certain extent for two component alloys. For example, such experimental evidence as is available indicates that the sorbitic structure in steel is the one which resists fatigue best. This structure is supposed to represent an extreme refinement of grain in which the particles of iron carbide are very small, and hence the particles of ferrite must also be very small. It is true that some of the iron carbide may be in solution in the iron, but it is more probable that the mechanical properties observed can be accounted for by an extreme reduction in the size and by the dispersion of ferrite and cementite particles. When these globules are made larger by heating to a higher temperature than that at which the sorbite was formed, granular pearlite results with reduced fatigue resistance.

When a high-carbon steel is quenched from above the critical range to form martensite, the metal becomes extremely brittle. The normal path of static rupture in brittle martensite is at the old austenite (solid solution of Fe_3C in gamma iron) grain boundaries. The path of rupture in fatigue has, so far as is known, not been ascertained. From certain tests on the resistance to fatigue of chrome-vanadium steel after various heat treatments, Dr. C. M. Olmstead, of the C. M. O. Physical Laboratories, Buffalo, found that the steel in the martensitic state, that is, as quenched, had a very much lower resistance to fatigue than after reheating to about 1100 deg. fahr. The maximum resistance to fatigue occurred by quenching and reheating to 1000-1200 deg. fahr. (538-648 deg. cent.), and there was very little difference between the specimens tempered at 1000 deg. and at 1200 deg. There was a marked difference, however, between these and the samples tempered at lower temperatures or those not tempered at all. This is the heat treatment that is commonly given to automobile parts which must withstand fatigue stresses, and which may be subjected to shock. The tempering of springs is done at a little lower temperature, but it is not certain that the spring structure is the one having the highest resistance to continued repetition of stresses.

It seems from the above that martensite is not a suitable material to withstand fatigue stresses, and that some intermediate structure between martensite and the annealed or normalized structure will have the maximum resistance to fatigue. This structure is called the sorbitic structure and corresponds to that used in automobile springs and other parts of automobiles which must resist fatigue and shock stresses.

Formulæ for Designing Parts Subjected to Repeated Stress

All formulæ which have been proposed for designing parts subjected to repeated stress depend upon extrapolation from test results and should therefore be regarded as tentative. Their use is justified only on the ground of necessity. Parts must be designed to resist repeated stress, and even formulæ derived from a confessedly inadequate experimental basis seem better than mere guesswork. Two types of formula have been used.[28]

In many discussions of data of repeated-stress tests, it is assumed that there exists some definite "endurance limit," that is, some stress, greater than zero, which can be repeated an infinite number of times without causing failure of the material. If such a limit exists it is certainly lower than the elastic limit of the material as determined by static tests, for actual failures of materials have occurred under repeated nominal stresses as low as one-quarter of the elastic limit as determined by a static test. Examination of test data indicates that the endurance limit is an assumption rather than a proved fact. It is usually determined by plotting a diagram with stresses as ordinates and number of

repetitions producing failure as abscissæ and estimating the stress for which the diagram seems to become horizontal. Various other methods have been proposed, but all involve this assumption.[18]

In 1910 a paper [9] presented before the American Society for Testing Materials pointed out that an examination of the results of numerous series of repeated-stress tests indicates that for nearly all the range covered the law of resistance to repeated stress may be expressed by the equation:

$$S = KN^{-m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

in which S is the maximum unit stress developed in the test piece, N the number of repetitions of stress necessary to cause failure, and K and m are constants depending on the material and somewhat on the manner of making the test. This is known as the "exponential equation for repeated stress."

Another form of expression for the above equation, and frequently more convenient, is:

$$\log S = \log K - m \log N \ldots\ldots\ldots\ldots [2]$$

If the logarithms of S and N are plotted, or if the values of S and N are plotted on logarithmic cross-section paper, Equation [2] is represented by a straight line. Fig. 7 shows the S-N diagram given by a series of repeated-stress tests. In Fig. 7*a* ordinary coördinates are used, but in Fig. 7*b* the coördinates are logarithmic. For large values of N the exponential equation gives in many cases values of S smaller than the observed values; in other words, the exponential formula seems to err on the side of safety.

It will be noted that the use of the exponential formula involves the assumption that any stress if repeated often enough will eventually produce failure of the material. Thus while both the endurance limit and the exponential formula are based on extrapolation from known data, the exponential formula seems to be an assumption on the safe side. The working stresses as developed by the two methods do not differ greatly except for members subject to more than ten million repetitions of stress. Above that number the exponential formula requires lower working stress, but even then the stresses given by the exponential formula are not impracticably low.

While nothing but tentative formulæ can be proposed now,[20] some features which a satisfactory formula for fatigue strength should include may be noted. It is probable that such a formula for any material will not depend on ordinary static qualities of the material such as elastic limit or tensile strength. It may depend on some form of elastic limit determined after the material has been put in a "cyclic" or "normalized" state by a number of reversals of stress. Such a formula will quite probably contain factors dependent on the surface finish of the part and upon the uniformity and regularity of its crystalline structure. It will contain a factor dependent on the range of stress during a cycle. Such a formula may contain a factor dependent on the probable number of repetitions of stress which the part may be expected to withstand during a normal period of service, or the result may be an "endurance limit"—a stress which the part is capable of withstanding so many times that even for modern high-speed machinery the number of repetitions may be regarded as infinite.

SPECIAL SUBJECTS NEEDING INVESTIGATION

Long-Time, Low-Stress Fatigue Tests of Metals. It is not known today whether machine or structural parts can withstand an infinite number of repetitions of any stress, however small. It is not known what share of blame for the occasional failures of test specimens or of actual parts in service under low nominal stress should be attributed to weaknesses in the metal structure: to localized damage to the surface with resulting increase of localized stress over nominal stress, or to "harmonics" of high stress due to interference of waves of stress traveling through the part. There should be undertaken an extensive series of long-time, low-stress tests on typical irons, steels, and other metals. It is doubtful whether any series of tests can settle the question of the existence of an endurance limit, but a considerable amount of test data for endurances up to, say, 100,000,000 repetitions will give a better basis for working formulæ than is now available.

Study and Comparison of Different Testing Machines for Fatigue Tests. Different testing machines for determining fatigue-resisting qualities do not always give consistent results. A series of tests of samples of several typical metals run on various testing machines should give some indications of the reliability of various types of testing machines and perhaps enable correlation to be made between tests on different machines. For all series of fatigue tests careful chemical and microscopic tests of the material should be made to insure uniformity both of chemical content and of structure. Careful tension, compression, and torsion tests should also be made so as to insure uniformity of static strength qualities, and to give data for the study of correlation between static strength and fatigue strength. Short-time, high-strain, repeated-stress tests and impact tests should likewise be made to give data for the study of correlation between toughness, impact resistance and fatigue strength. All test specimens should be prepared with great care and surface conditions be kept as uniform as possible. It appears that this uniformity could be best secured by giving the surface a high polish.

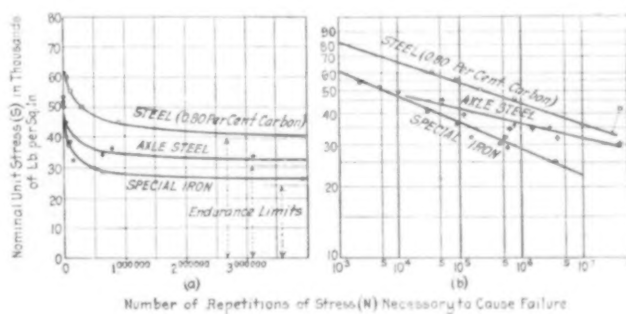

FIG. 7 STRESS-STRAIN DIAGRAMS

Relative Importance of Surface Condition and Structural Characteristics as Shown by the Microscope. It seems practically certain that fatigue fractures may be started either at a surface imperfection or at an internal flaw, such as a "snowflake" or a "transverse fissure." The importance of these two types of defect might well be the object of experimental study. In connection with such a study there should be a study of methods of detecting internal flaws, such as deep etching [21], and a study of methods of indicating the degree of perfection of surface finish.

Effect of Grain Size of Metal on Fatigue Strength. On this subject Rosenhain [22] says:

> The question then arises whether the increased size of crystals produced in a simple metal by prolonged heating is injurious or otherwise, so far as the useful properties, and more especially the mechanical properties, of the metal are concerned. There can be little doubt that within reasonable limits the mechanical properties of a simple metal are better the smaller the constituent crystals of which it is built up. Under the tensile test, coarseness of structure usually results only in a slightly lowered yield point, while the ultimate stress and the elongation are little impaired, although the reduction of area at fracture is sometimes markedly less. On the other hand, under both shock and fatigue tests, a coarse structure, even in a simple metal, gives unsatisfactory results.

Tests and service records quoted by Jeffries and by Ruder tend to confirm this opinion in the case of copper. Fine-grained copper is very much more resistant to repeated stresses than coarse-grained copper. Also if the elastic limit of fine-grained metals is determined by delicate instruments, it is generally found to be greater than that of the same metals in the coarse-grained state. Systematic tests should give us a firmer basis for conclusions in this important phase of fatigue phenomena.

There have been found no records of microscopic analyses dealing with the path of rupture under repeated stress in steels having various structures from martensite to the normalized state. A study of the path of rupture and the manner of rupture in these samples would be most interesting.

Development of Special Tests for Fatigue Strength. At present there is no short-time test for fatigue strength which has been proved to give reliable results. Some tests which give promise of usefulness are:

1 The Rise-of-Temperature Test used by Mr. Stromeyer.[22] In this test the highest reversed stress which a specimen can stand without appreciable rise of temperature is taken as an index of fatigue strength.

2 The Development of "Mechanical Hysteresis." If a fatigue failure is in progress in metal subjected to repeated stress, very small amounts of energy are lost during every cycle of stress. The energy lost during each cycle may be too small to measure, but after some hundreds or thousands of cycles the cumulative effect of the losses may become appreciable. This loss may appear as a "loop" in the stress-strain diagram for a complete cycle of stress, and this indication may be detected at a comparatively early stage of the fatigue failure. Dr. Stanton of the British National Physical Laboratory has made some experimental study of this development of "mechanical hysteresis," as this loss of energy is called.[7] It is possible that mechanical hysteresis may be studied by the dying out of vibrations set up in a test piece, as has been proposed by Boudouard.[21]

3 Magnetic Testing of Steel for Fatigue Strength. The structural damage done while a progressive fatigue failure is occurring may, possibly, be detected and measured by the change in magnetic permeability of the steel. Burrows, Dudley, and Sanford[28] have done some experimental work on this subject, and magnetic analysis seems worthy of study as an index of fatigue strength.

4 Impact Tests and Repeated-Impact Tests. Although the action of metal under impact is very different from its action under repeated stress, yet both impact and repeated stress seem to emphasize local irregularities and imperfections of surface or structure. It may be that a repeated-impact test may be devised which will give a reliable measure of fatigue strength, and which will do so in a comparatively short time. Such tests seem worthy of study, though their value as tests of fatigue strength cannot be said to be established.

It is believed that the foregoing paragraphs outline fundamental investigations, many of which should be undertaken at an early date. Experimental study of typical metals under long-time, low-stress tests; study by means of the microscope of the phenomena of fatigue failure in metals of various crystal structures; and study of reliable test methods of determining fatigue strength constitute, in the opinion of the Committee, the fundamental line of research in fatigue phenomena. Once such fundamental tests have made fair headway, especially the determination of a reliable test for fatigue strength, a large number of problems call for study, among which may be mentioned: the effect of surface finish; the effect of various heat treatments on fatigue strength; the effect of cold-working and of hot-working of metal on fatigue strength; the effect of intervals of rest in restoring fatigue strength; the effect of range of stress; the effect of compound stresses; the effect of speed of repetition of stress; a study of waves of stress in machine members; and fatigue studies of full-sized members, such as railroad rails, riveted joints, wire ropes, car and truck axles, crankshafts, and power-transmission shafting.

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Under the sundry civil service bill the Council of National Defense has had its unexpended balance for the fiscal year ended June 30, 1919, reappropriated to it. Plans are now being matured for the return of the Council to its peace-time functions, which, according to the Act of Congress creating it, are "the coördination of industries and resources for the national security and welfare and the creation of relations that will render possible in time of need the immediate concentration and utilization of the resources of the nation." It is the intention of the Council to collect, study and centralize in a scientific way all information bearing upon the national defense, particularly with regard to the mobilization of industries, science and labor in time of war.

The entire expenses of the Council up to May 1, 1919, were only $1,500,000. It is estimated that more than $3,000,000,000 was saved to the Government by the prices which the Council's experts on raw materials, minerals and metals made in the procurement of iron and steel products.

Torpedo-Boat Destroyers in the Making

By COMMANDER JAMES REED,[1] U. S. N., MARE ISLAND, CAL.

The American destroyer and the spectacular part which it played during the war in convoying troops and combating the submarine are subjects of almost universal knowledge and interest. The destroyer has fully justified its existence as a distinct naval type, not only because of its value for scouting, screening, convoy service, and coastal attack, but also on account of its use in major engagements between fleets. The development of the destroyer has been a logical one and Commander Reed first presents in his paper a brief historical review of modern American torpedo craft. This review is followed by a non-technical description of the construction of the so-called "Liberty Destroyer," the Ward, which was launched on June 1, 1918, 64 per cent complete, and only 17½ days after the laying of the keel. This is a record in ship construction and one that has never even been approached. It is a remarkable achievement and when contrasted with the two to four months required to complete some of the earliest torpedo vessels it brings a realization of the great advances that have occurred in the art of shipbuilding.

THE torpedo-boat destroyer, or more briefly, the "destroyer," as the type is generally known, is strictly a logical development of the torpedo boat of Cushing, just as the modern superdreadnaught is a development of the *Monitor* of Ericsson. The destroyer is the answer to the torpedo boat; but as the destroyer proved capable of performing all the functions of her smaller prototype and also possessed more speed, seaworthiness, comfort, radius of action and power of attack and defence, it soon forced out the smaller torpedo boat, which at best was but a small, dirty, uncomfortable and weak unit.

Fig. 1 U. S. Torpedo Boat *Farragut*
This vessel made a mile during its trial run in 1899 at the rate of 31.7 knots

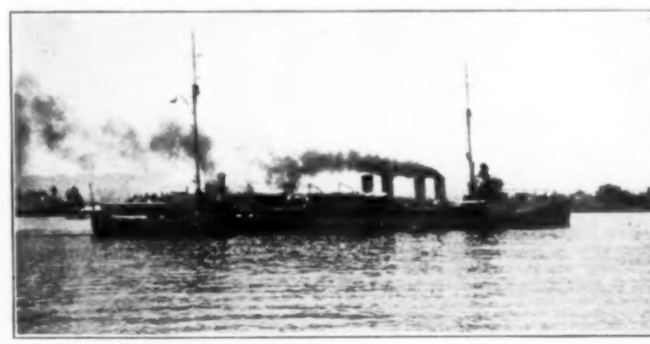

Fig. 2 U. S. S. *Shaw*

The demands for higher and higher speeds—and sustained sea speeds at that—have resulted in great increases in horsepower, structural strength, and freeboard. The latest types of United States destroyers have a speed of 35 knots in cruising trim, which means practically in war condition, and not over a measured mile in stripped condition and with favorable wind and tide, under which circumstances certain marvelous foreign speed records are known to have been made. It is accordingly satisfying to learn that in joint operations during the war our destroyers compared more than favorably with the British and French as regards strength, seaworthiness, speed, armament, and comfort in accommodations for both officers and men.[2]

The designing and building of a successful type of modern destroyer brings into play the highest skill of the naval architect, the marine engineer, and the shipbuilder, due to the sacrifice of all other considerations to those of speed, armament, seaworthiness, strength and cruising radius. The destroyer is really an overgrown racing motorboat, and her lines are therefore radically different from any other type of sea-going vessel. For example, the ratio of beam to length is less than 1:10, and her draft is very shallow for her length, being only 9½ ft. for the latest 315-footers.

Conclusions drawn from the world war have not terminated the long discussion upon that favored topic among all naval authorities—as well as interested laymen—in regard to the relative value of the superdreadnaught type of warship. However, all authorities are agreed that the torpedo-boat destroyer has come into its own and has fully justified its existence as a distinct naval type, not only for submarine hunting but also for efficient use in convoy service, in scouting and screening, in coastal attacks, both alone and in conjunction with ships of heavier type and with aircraft, and even in major engagements between fleets.

Early Types of Destroyers

The early torpedo boats carried the torpedo on a spar extending from the bow of the vessel, and the method of attack consisted in steaming head-on for the enemy vessel and exploding the "spar" torpedo on contact. Of course such a torpedo would be practically harmless to a modern superdreadnaught with its extravagant protection against torpedo attack. These boats were small and not very fast according to present-day standards, but with the inefficiency of gunfire in those days they could have probably been successfully used for night attack at least, if one were reconciled to the probable loss of the attacking boat and crews. War service on board one of these torpedo craft would have proved highly hazardous, especially since this was long before the invention of the wonderful non-sinkable life-preserver suits which have been popular for Atlantic travel during the past three years, and in which it is reputed one can float around until death from starvation occurs.

With the development of a more or less satisfactory self-propelled torpedo by Whitehead about 1880, the spar-torpedo boat—which was really not much more than a picket boat—gave place to a larger, speedier, and more seaworthy type of vessel, with corresponding increases in complement and cruising radius. These boats launched their torpedoes from single tubes on deck, and their power of attack was limited to their torpedo equipment as the remainder of their armament consisted only of machine guns or rapid firers of the smallest caliber.

The first torpedo boat in the United States Navy using self-propelled torpedoes was the *Stiletto*, a little wooden yacht 88 ft. 6 in. long by 11 ft. beam by 3 ft. draft, purchased from Herreshoff for $25,000. She was single-screw, of 350 hp. and

Presented at a meeting of the San Francisco Section of The American Society of Mechanical Engineers, April 16, 1919.

[1] Construction Corps, U. S. Navy Yard. Mem. Am. Soc. M. E.

[2] During the whole period of their operations abroad no American destroyer ever returned to port because of stress of weather.

developed a speed of 18.2 knots. For many years she was employed at the Torpedo Station, Newport, R. I., for practice firing of torpedoes.

The first steel torpedo vessel for our service, very appropriately named the *Cushing*, was authorized August 3, 1886, and built by Herreshoff for $82,750. She was 138 ft. 9 in. long by 14 ft. beam by 4 ft. 10 in. draft and displaced 105 tons. Her engines were twin-screw, vertical, quadruple-expansion, and her speed 22.5 knots. Her armament consisted of three 18-in. Whitehead torpedo tubes and three 1-lb. rapid-fire guns, and her complement was three officers and twenty men, the same complement, it may be noted, as that of the famous little submarine chasers of the present war.

The *Cushing* was followed by the *Ericsson, Foote, Rodgers, Winslow, Du Pont* and *Porter*, all of which saw service in the Spanish-American War, and hard service at that, as any of the officers who were on duty on board them will testify, even though they did not operate in the cold, foggy and boisterous North Sea in pursuit of the elusive "tin fish."

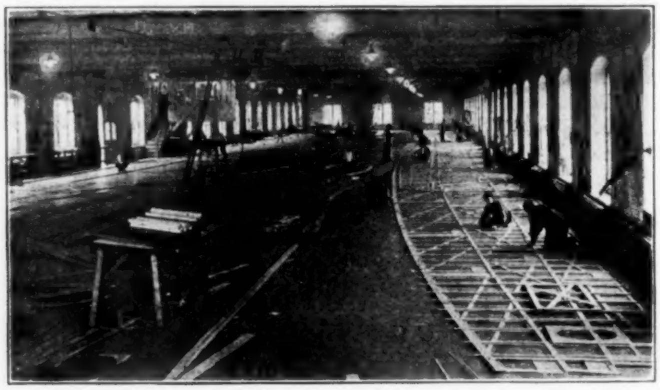

Fig. 3 The Mold Loft
During the laying out of the molds for the main deck of a destroyer.

In the group of torpedo boats placed in commission shortly after the Spanish-American War, the *Farragut* (Fig. 1), designed and built at the Union Iron Works, San Francisco (now the Union Plant, Bethlehem Shipbuilding Corpn., Limited), is worthy of mention. This little vessel on one trial attained a speed over a measured mile of 31.7 knots, which was an extremely high speed for any war vessel at that date (1899). It is of interest to note that the *Farragut* still holds the record from Mare Island Navy Yard, Cal., to San Diego, a distance of 500 miles, which she covered in 1910 at an average speed of 27.3 knots, a remarkable performance for a coal-burning vessel of her size. She served throughout the present war and on one occasion in 1918 made over 26 knots in service while heavily loaded.

About 1902 the first of a group of sixteen destroyers for the American Navy were completed and these boats have been in continuous service ever since, all having done good work in the war zone. Their dimensions were practically identical; namely, displacement (actual), about 560 tons; speed (average), 28 knots; armament, two 3-in. guns, five 6-pounders and two single torpedo tubes.

These boats were followed by several classes of destroyers gradually increasing in size and power until the United States entered the present war. At that time the latest destroyers were of about 1000 tons displacement, 30 knots speed, carried four 4-in. rapid-fire guns, and four double torpedo tubes. (The depth-charge armament was installed afterward.) These were "high bow" boats, with a forecastle deck ending at the bridge, as will be seen in Fig. 2. Soon after we entered the war the first of the "flush deck" type of destroyers was produced and this type has now been standardized for our Navy.

The Navy's Latest Type of Destroyer

The general characteristics of the latest destroyer, as compared to the little *Stiletto* previously mentioned, will possibly be of interest. The new type has a length of 315 ft., a beam of 30 ft. 10 in., and a draft of 9 ft. 4 in., with a displacement of about 1200 tons. The armament consists of four 5-in. rapid-fire guns, two 3-in. anti-aircraft guns, three machine guns, four triple torpedo tubes, and large numbers of depth charges.

The inboard profile of one of our modern destroyers reveals the fact that an enormous amount of space is given over to machinery. The crew of 130 men sleep in wire-mattressed folding bunks instead of in hammocks as on the larger ships, and each man has a metal locker for his effects. The men mess and sleep in the same compartment. The officers' quarters are roomy and comfortable and equipped with metal furniture throughout.

Forced ventilation is provided in all living spaces by means of electric blowers. Other electric equipment consists of laundry machines, refrigerating unit, and a coffee percolator, toaster and warming oven for the pantry. The galleys have oil-burning ranges, also steam coffee urns and steam cookers. Running water and showers are also provided for both officers and men, but tubs are not installed because of the space required, the larger consumption of fresh water, and the weight involved.

This question of weight is a most serious one in vessels of such high speed and most careful designing is necessary in order to secure the maximum strength with the minimum weight. In recent years great advances have been made possible through the generous use of high-tensile steel, for by its use radical reductions in scantlings throughout the vessel have been effected. Attention is invited to the extreme lightness of plating and shapes throughout a modern destroyer. The lightest plating on bulkheads is only 5 lb., or 3/20 in., approximately. Deck thicknesses vary from 5 to 20 lb. per sq. ft., and shell plating from 7 to 18 lb. per sq. ft. (7/40 in. in thickness).

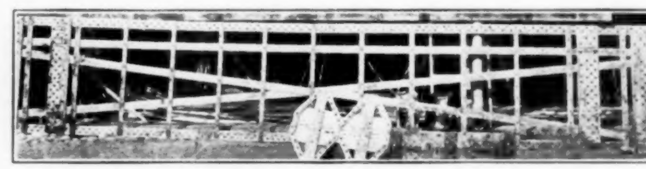

Fig. 4 Shell Molds
Full instructions for the "layer out" are painted on each mold.

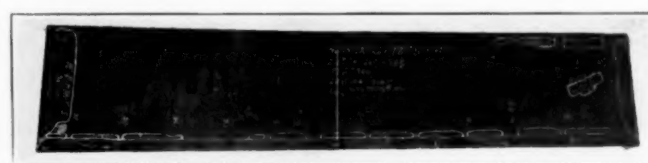

Fig. 5 A Plate Laid off Ready for Fabrication

In addition to the use of extremely light materials throughout, holes for lightening purposes are punched or burned by oxy-acetylene in all floors, web frames, girders, brackets, etc., and wherever practicable corners are snipped off beams and frames; butt straps are also scalloped between rivet holes, etc., and all this is done to save a few pounds. In connection with the light scantlings of torpedo craft, the annual report of the Chief Constructor of 1897 bears this remarkable recommendation: "The remaining boats will be in reserve and must be kept in good condition ready for service at short notice. To do this most economically and to prolong the life of the boats as far as possible, they should be *kept out of the water and under cover*."

In spite of all this cutting down in weight throughout the whole structure these vessels have proved wonderfully strong in service, as is demonstrated by several serious casualties experienced in the war zone, notably the one where the stern of the *Manley* was blown off by the explosion of her own depth charges, and the case of the *Shaw* (Fig. 6), where the entire bow from the bridge forward was cut off by a collision with the mammoth Cunarder *Aquitania* while zigzagging at a speed of 24 knots. The *Manley* was towed into port, but the *Shaw*

proceeded under her own steam, and both have since been repaired and placed in service. Due to the intricate watertight subdivision of these boats, they are practically immune from sinking as a result of any ordinary casualty in service.

Another way to reach an appreciation of the exceptional strength of these light craft is to consider the tremendous horsepower installed in them in order to secure the speed demanded. In the latest boats upward of 30,000 shaft hp. has been developed on trial, which power approximates closely to that of many of the latest superdreadnaughts. This power is carried on a displacement only one-twenty-fifth as great as in the battleship, and in a space of less than 4200 sq. ft. for boilers, engines and all auxiliaries. Hence, it will be seen that although to provide sufficient power for these destroyers is comparatively easy, to house it in the hull to be driven, and to design and fit proper foundations and strength members to hold it are serious problems in such a small hull where weight saving is of such vital importance.

Only those who have been on board of one of these destroyers while it was tearing into a head sea at a speed above 36 knots per hour can sense the tremendous power their slender, quivering hulls contain. Their main engines consist of steam turbines connected through reduction gears to two shafts driving twin screws up to 480 r.p.m. Skill in balancing all rotating parts has reached such a high degree that there is practically no vibration due to the engines or propellers even at the highest speeds, and with regard to cruising radius the latest class of destroyers carry sufficient fuel oil to cross the Atlantic at a speed above 20 knots.

Modern Methods of Building Destroyers

After the general characteristics for a proposed class of destroyers are determined by the General Board of the Navy, and approved by the Secretary, tentative plans and estimates are prepared by the Bureaus of Construction and Repair, Steam Engineering, and Ordnance, and these form the basis of the recommendations of the Secretary for the necessary Congressional appropriations. When the appropriations are made the Bureaus concerned get out contract plans which, after approval by the Secretary of the Navy, are forwarded to various shipbuilding firms and navy yards for bids. These plans are general in character, and contain no details. After the acceptance of a bid, which frequently offers a modified design embodying the builder's ideas, the following steps are involved in the building of the destroyer:

1. Ordering of the material
2. Preparing detail plans for both hull and machinery
3. Laying down lines in the mold loft and preparing the molds (construction of machinery is usually started at about this time)
4. Laying off and fabricating structural material
5. Assembly of fabricated material
6. Erection of fabricated material (hanging and bolting up)
7. Riveting and calking
8. Testing
9. Launching
10. Installing of machinery, armament and outfit complete
11. Dock, builders' and acceptance trials of the vessel
12. Commissioning and fitting out.

Ordering of Material. Orders for material are made up from Material Schedule Sheets, which show the type, dimensions, weight, and distinctive marks of each piece entering into the structure, and when required the assembly drawing on which it appears. The main orders to the steel mills do not, of course, go out in such detail as the various weights and sizes are grouped for the mills, wherever practicable, into classes of more or less standard dimensions, and the detailed schedules follow later. Orders for main and auxiliary machinery not supplied by the shipbuilder from his own works are placed as early as possible, since it is machinery, not hull completion, that determines the date of delivery of the finished vessel.

Preparing Detail Plans. There are about 1100 plans required to cover all the work on one of our latest type destroyers and a great saving in both time and expense has been effected by the Navy Department in the use by several contractors of prints from one set of the detail plans, instead of each contractor developing his own plans, as was the former custom.

Laying Down Lines and Preparing Molds. This consists in striking in on the smooth floor of the mold loft the lines of the vessel in full size. The forms of all naval vessels are determined by towing actual models in the Model Tank at the Washington Navy Yard and recording the resistance of each. These lines are the intersections of the hull and decks of the vessel at certain regular stations with three different planes at right angles to each other as follows:

a The vertical longitudinal plane (sheer plan)
b The horizontal longitudinal plane (half breadth)
c The vertical transverse plane (body plan).

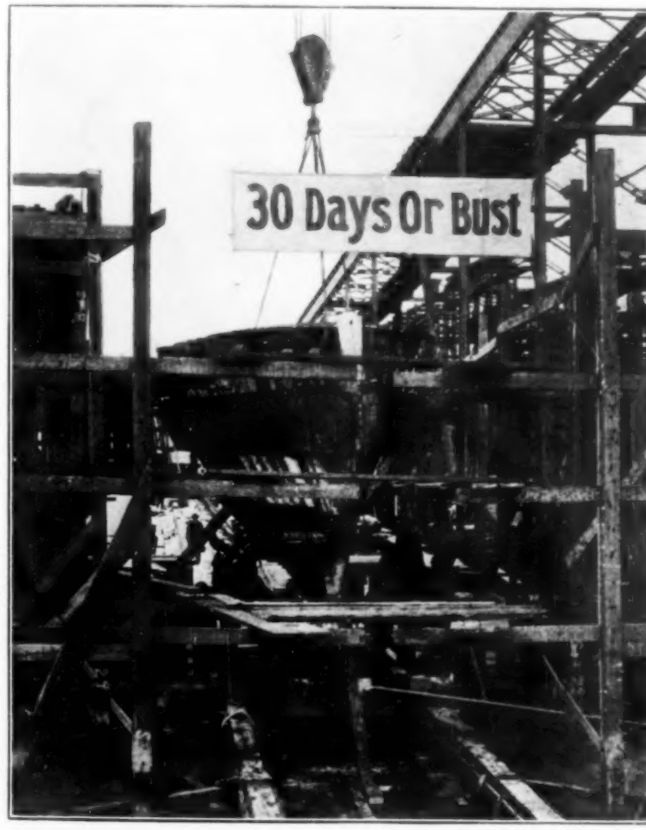

Fig. 6 The *Ward*—First Day
Lowering the "assembled stern" into place.

From these lines, together with certain additional ones that are used in those parts of the ship where extreme curvature occurs, the expanded dimensions as well as the shape of every piece entering into the ship's structure may be obtained, and a wood, paper or metal pattern, as shown in Fig. 3, can be made up showing all the details of the fabrication of the piece.

Every seam, butt, lap, cut and bevel of the plate or shape, as the case may be, is indicated on its proper mold (Fig. 4), which also usually carries the piece number (from the Material Schedule), the location in the ship, the description, and the job order number on which the work is to be performed. Heavy paper is used for some molds, and by certain shipbuilders even to the exclusion of wood. At the Mare Island Navy Yard, in order to keep out moisture and avoid shrinkage, all wooden molds are shellacked by the use of a pneumatic painting machine.

The loftsman is a real practitioner in analytical and descriptive geometry, and upon the accuracy of his work depends much

of the success or failure when the fabricated material comes to the shipfitter for erection. Half-holes, unfairness, etc., result from inaccurate mold-loft work and these errors are very serious in a destroyer where all structural members are thin, and where fairness of holes and of form throughout is essential.

Laying Off and Fabricating Material. The molds go from the mold loft to the shipfitter, who lays off the structural material by clamping the mold in its proper position upon the steel plate or bar and then marks up the piece according to the instructions on the mold, which is really his pattern for cutting the goods. There are 411,252 rivets by actual count in one of these destroyers, and it will be noted that each rivet hole is indicated on a

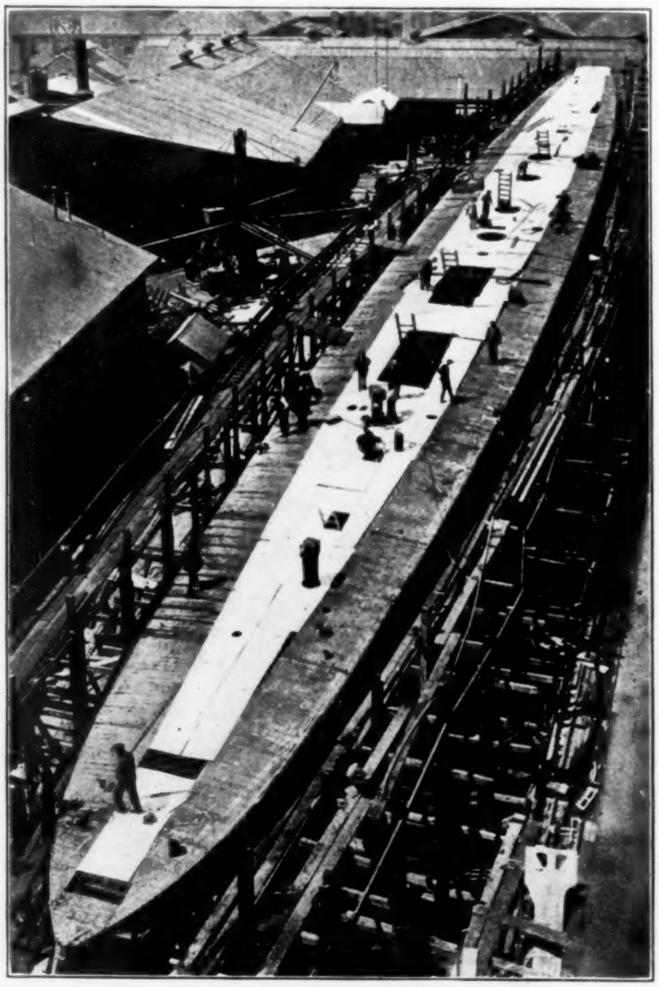

Fig. 7 The *Ward*—Fifth Day

mold where the universal system is used, as at Mare Island, and the location of each hole is punchmarked on to the plate or bar in laying them off as shown in Fig. 5. The material then goes to the shop for fabrication, that is, rolling (if required), shearing to dimensions, punching rivet holes, edge planing, punching or burning out lightening holes by the use of oxy-acetylene torch, and weighing. The weight of every piece entering into the structure of the ship is carefully estimated in advance in order that the displacement of the vessel may not exceed that for which it was designed, and a constant check is kept on this by actually weighing everything prior to placing it on board the vessel. It is not unusual for a destroyer to actually displace on completion a tonnage of water which will vary less than five tons from the displacement which was estimated in connection with her design. This is an accuracy of 0.4 per cent for a 1200-ton vessel.

Assembly of Fabricated Material. Prior to laying the keel practically every piece of structural material is laid off and fabricated, ready for assembly, and in the case of the *Ward* the following preliminary assembly and riveting was performed:

a Keel in sections with clips for floors and frames attached
b All main structural bulkheads complete with bounding angles
c Web and belt frames and beams
d Frames with floors and bulkheads attached
e Deck houses
f Stern of ship including stern post and frames to bulkhead.

Erection of Fabricated Material. Having assembled the material as outlined in preceding paragraph, the keel of the *Ward* was laid at 7.45 a. m. on May 15, 1918. As soon as the keel was in place riveting the various sections together proceeded, and the various frames with floors attached were bolted to the clips on the keel, while the main structural bulkheads were dropped into place complete. The frames were temporarily held in proper register by a longitudinal rib-band shore at the turn of the bilge and another support from the scaffolding at the top of the sheer strake near the deck edge. The bottom plating was then placed in proper position and bolted to the frames, and the stem erected and the fabricated stern of the ship placed in position, as indicated in Fig. 6. Next the plating of the platforms and decks was laid on (Fig. 7), and as the bolting-up throughout the structure proceeded rivet holes were reamed throughout and riveting gangs followed. The deckhouses were placed in position as were all other deck erections (Fig. 8), such as ventilation trunks, foundations, skid beams for carrying boats, davits, etc., as fast as the deck was ready to receive them.

Riveting and Calking. In the assembly of the fabricated material 183,000 rivets were driven prior to laying the keel of the vessel, and 165,000 were driven thereafter before launching. Eighteen riveting gangs were employed, and the average number of rivets of all kinds per day per gang was 587.5. Work on the vessel was not continuous, averaging only eighteen hours out of each twenty-four. Overtime in general was restricted to two hours, but a few trades worked three hours over eight hours during part of the 17-day period. The ordinary rough-fisted riveter, trained in structural-steel riveting, or on merchant work, makes a sorry job of destroyer riveting, where the greatest care and skill are necessary to insure a tight, well-shaped joint without hammering of the light high-tensile plating adjacent to the rivet hole. Careful packing and thorough bolting up are essential to a properly watertight or oiltight job. The calking must also be skilfully performed on these light vessels or the very object of this work will be defeated.

A few of the records of the best Mare Island riveters on the *Ward* may be of interest and Table 1 is accordingly given.

Testing. The strict requirements of the Navy specifications in regard to bulkhead strength, water and oiltightness, are insured by actually testing the various compartments under a head of water, while others are tested under air pressure. Of course the fire rooms must be airtight to meet the demands of forced-draft operation in service, these spaces being under pressure at all times while steaming. Decks, hatches, airports, deckhouses, etc., are tested for tightness by playing a hose on them.

Launching. The operation of launching consists essentially of simply transferring the weight of the hull from the blocking, cribbing and shores, upon which it has been supported during construction, to two parallel launching ways, one running each side of the keel for a portion of the vessel's length. These ways are in two parts, the lower fixed section comprising the ground ways, the upper, which carries the cradle in which the ship rests, the sliding ways. The ways are laid at an inclination to the horizontal, usually about 25/32 in. to the foot and the smooth facing surfaces of the ground and sliding ways respectively are thoroughly greased. Upon releasing a trigger, dropping a "dog shore," or sawing through a timber holding the sliding ways to the fixed ways, the vessel starts on her journey down the ways. Actually, there is a great deal of careful calculation necessary preliminary to this launching operation, which unfortunately does not always pass off smoothly. Sometimes the ship balks refusing to start, or goes so slowly that she sticks, in which cases recourse is had to jacks, towlines, vibration by running on deck,

TABLE 1 RECORDS OF INDIVIDUAL RIVETERS DURING CONSTRUCTION OF DESTROYER *WARD*

Riveter	No. of rivets	Size of rivet, in.	Hours
May 18;			
Towers[1]	1062	5/8-3/4	9
Blount	838	3/4	9
Posedel	811	3/4	9
May 19;			
Blount	1165	5/8-1/2	8
Towers	1016	5/8-1/2	8
Swanson	901	5/8-1/2	8
May 20;			
Towers	1245	5/8-1/2	10
Blount	1165	5/8-1/2	10
Gaarder	1147	5/8-1/2	8
Swanson	1043	5/8-1/2	10
May 21;			
Towers	1349	5/8-1/2	10
Schnerdewind	1278	5/8-1/2	10
Powell	1203	5/8-1/2	10
Blount	1165	5/8-1/2	10
Swanson	1073	5/8	10
Gaarder	997	5/8	8
May 22;			
Towers	1500	5/8-1/2	10
Blount	1302	5/8-1/2	10
Schnerdewind	1129	5/8-1/2	10
Beab	1090	5/8-1/2	10
Gaarder	1060	5/8-1/2	8
Powell	912	5/8-1/2	10
Swanson	800	5/8-1/2	8
May 23;			
Towers	1800	3/8-1/2	10
Gaarder	1333	5/8-1/2	10
Powell	1095	3/4-5/8	10
Schnerdewind	989	3/4-5/8	10
Blount	879	3/4	10

[1] L. A. Towers' record was 13,343 shell rivets (1/2 in. to 3/4 in.) driven in ten working days, or a total of 97 hours.

FIG. 8 THE *Ward*—TENTH DAY

etc. If all means fail, it is necessary to jack her up and start over again.

Installation of Machinery. The installation of machinery and miscellaneous fittings is usually begun before launching, and completed after the vessel has been launched, but in the case of the *Ward* this work was performed overboard, her boilers, gears, main turbines and auxiliary machinery all being placed on board at the fitting-out pier. The controlling feature in the completion of a destroyer nowadays is the expedition with which the coppersmith performs his work. The country was scoured for skilled men in this trade, but the demands were never met, either as regarded the Navy or the Shipping Board.

Trials. Dock trials are held as soon as the machinery installa-

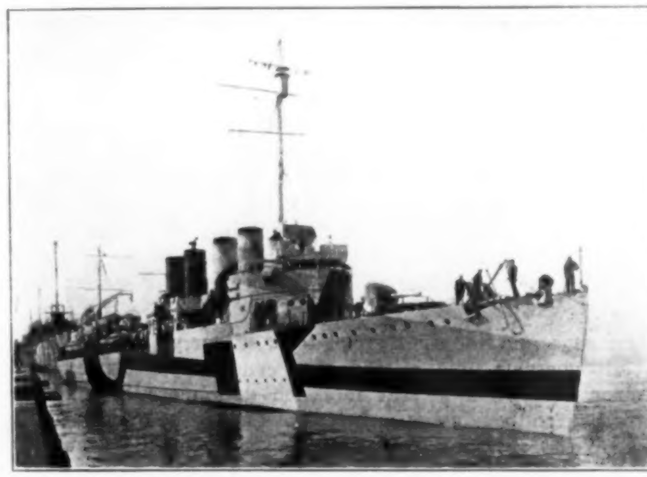

FIG. 9 THE *Ward* COMPLETE AND READY FOR TRIAL TRIP

tion is complete, and if everything functions satisfactorily, the vessel proceeds on a "builder's trial," in order to "run in" her machinery and insure that everything will operate smoothly on the official trials before the Naval Trial Board, composed of officers experienced in naval construction, engineering and ordnance. These trials are very severe and consist of continuous runs, of several hours' duration each, at various speeds up to the maximum. At least one vessel from each class is carefully "standardized," that is, the vessel is run over a measured-mile course both with and against the tide at varying speeds up to the maximum, both the revolutions per minute and the horsepower required being carefully observed during each run. From these results curves are plotted, which give a ready means of ascertaining the horsepower or revolutions required for any given speed.

All of the above trials are held at the vessel's normal displacement, which was specified in the contract. Additional tests carried out during the trials are on the steering gear, anchor gear, and gun firing (to test foundations). A thorough report, embodying the observations of the Board on the design, construction and performance of the vessel, is submitted to the Department and any weaknesses or alterations are corrected in the boat under trial, also in future boats. By this system a continual improvement in design and construction has resulted.

Commissioning. Navy-yard-built destroyers are placed in commission before the trial runs are held, these being conducted by Navy personnel. The *Ward* was placed in commission on July 28, 1918, 74 days after the laying of the keel. Her machinery installation was not complete on this date, but she was commissioned so that stores could be placed on board, the ship's organization perfected, and the vessel in all respects made ready for departure the moment her machinery installation was completed, which was on September 1, 1918, as per schedule.[1]

(*Continued on page* 781)

[1] The fact that serious difficulties developed with certain auxiliaries supplied by private contractors in no way detracts from the merit of the performance represented by the completion of this vessel, ready for sea in 104 working days, especially when the intricacy of her design and the enormous power she carries are considered. Our earliest torpedo vessels, smaller, simpler and of relatively low powers, took from two to four years to complete.

Pulverized Coal as a Fuel for Boilers

A General Study of Its Characteristics and the Operating Conditions Met With in Its Commercial Applications; also a Discussion of the Nature of Flame, Types of Burners and of a Design of a Pulverized-Fuel Furnace for a 500-Hp. Boiler

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BEFORE entering into details concerning pulverized coal, it is not out of place to emphasize that in the process of burning fuels certain very definite operations take place which depend strictly on the physical and chemical properties of the fuels. The reactions occurring, the quantity, quality, density and the temperature of the gases that result during combustion, and their effects, as well as the practical rate of burning to secure perfect or nearly perfect combustion, have all been defined and clearly enough so for practical application. Unfortunately, however, because of the cheapness of all fuels, these matters have not received the attention their importance deserves. We are more interested in the calorific value of fuels per unit weight, regardless of whether they are solid, liquid, or gaseous; that is, we consider a pound of fuel as the container of a given number of British thermal units and on that basis are prone to use one form of fuel or another in any service and to expect equal results.

Our conception of the thermal form of energy is still that of an imponderable fluid instead of a condition of matter. The common conception is that radiation does more heating than convection and conduction, whereas in reality the opposite is the case. We speak freely of heat transfer from one body to another instead of its propagation, and almost without regard to the relative value of specific temperatures, conduction, convection and radiation. We overlook the fact that the available heating capacity of a fuel is the surplus left from that developed in its conversion to the ultimate gaseous oxides, and that we can use only a portion thereof, depending not on the temperature that develops during combustion, but on the nature of the work to be done and the temperature at which that work can best be done. The energy consumed by combustible materials in the transition from the gaseous, the liquid and solid forms into the ultimate gases is different for the same quantity of combustible constituents. Each case involves a different time element, which is comparatively short with gases, longer with liquids and longest with solids. The presence of elements other than carbon and hydrogen, and their more or less complex formation, increase the endothermal losses, and affect directly the temperatures that develop. In consequence, not only is the heating value of each kind and form of fuel different from that expected from preliminary analysis, but the effects of the resulting properties are different. In burning lump coal, on account of the slow rate of combustion sufficient time is allowed to compensate for its variable structure and impurities. Liquid and gaseous fuels, on account of their uniform structure, give constant deflagration regardless of the rate of burning, and the effects of the actions that take place in burning are of less consequence.

With pulverized coal, on account of its rapid combustion, the effects due to the structure and amount and nature of the impurities are conspicuously manifested by the varying high temperatures and the unsteadiness of deflagration. The necessity of carefully considering the actions that take place in the combustion of powdered coal to adequately provide for their efficient utilization is thus made apparent. When dealing with the combustion of fuels and with heating we are confronted with problems concerning the molecular structure of materials in all their possible forms, and as such we should treat the matter on a different basis than mere B.t.u. considerations.

Advantages and Disadvantages of Pulverized Coal as a Fuel

The merits of pulverized coal as a fuel, briefly stated, are as follows:

a If ground sufficiently fine the entire combustible content of the coal can be burned, thereby effecting fuel economies hitherto not attainable even with the better grades of coals burned under favorable conditions.

b It permits the use of all grades of coal, including peat and lignite, with an approximately equal degree of thermal efficiency for the same service, and increases very materially the energy that can be derived from the world's supply of coal

c It possesses very largely the facility of control and combustibility of oil and gas fuels, thereby placing coal on a parity with these fuels.

The limitations of pulverized coal are:

a The very high temperatures attending its efficient combustion (see Table 1) and the unsteady mode of its deflagration, necessitating special furnace construction to secure reliable service and to realize the possible economies it affords, preclude its ready application to existing equipment

b The operating cost and attention required to maintain the necessary apparatus for its use may more than offset the fuel economies that can be effected in small independent services

c The presence of ash, which may not always be collected and held under control

d The human element, which will not submit to the peculiarities of its nature.

TABLE 1 APPROXIMATE COMBUSTION TEMPERATURES OF CARBON AND BITUMINOUS COAL AND THE RESULTING PERCENTAGES OF CO_2

Percentage of excess air	0	25	50	75	100	125
Combustion temperature, deg. fahr.:						
Carbon	4000	3450	3000	2625	2350	....
Average bituminous coal	4860	4000	3325	2860	2500	2220
CO_2 per cent	20.8	16.5	13.8	11.8	10.2	....

For flexibility and nicety of operation gaseous fuels rank first, being followed respectively by liquid fuels (oils), powdered coal and solid (lump) fuels. On the basis of cost they assume exactly the reverse order. Economy depends on the nature of the service and local conditions.

Preparation of Pulverized Coal

The valuable feature of pulverized coal is that by reason of its divided state it can be brought en masse into intimate contact with the air necessary for its combustion, and in consequence, when injected into a suitably heated hearth it burns completely, deflagrating almost as readily as atomized oil.

Obviously the first requisite is to render the fuel into as fine particles as is possible, so that when mixed with air the mixture shall assume the form of a homogeneous gas. This analogy is comparative only, for no matter how finely broken and thoroughly mixed with air the coal particles are, they retain their solid structure and are therefore subject to a very arduous process of combustion, which is responsible for the attendant high temperatures that result.

The standard established in cement-mill practice, generally adopted for all purposes, is that 85 per cent of the powder shall

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[2] Mechanical Division, The J. G. White Engineering Corporation.

pass through a 200-mesh screen, and 95 per cent through a 100-mesh screen. Coal so ground weighs from 35 to 45 lb. per cu. ft. and 1 lb. of it can be carried in suspension through smooth piping in about 5 lb. of air moving at low velocities. Experience shows that under favorable conditions 100 per cent 60-mesh powder can be burned satisfactorily. This coarse fuel necessarily requires a longer time for its complete combustion and it can only be carried in suspension at high velocities. Its use, therefore, would be permissible only in furnaces which provide a long path for the resulting flame. In short chambers operating at low velocities these large particles fall to the bottom of the chamber before being consumed and coke, the result being a loss of fuel.

Granulated coal ranging in size from 1/4 in. to powder has been used as fuel for boilers aboard ship, it being blown into specially constructed hearths. This method has given good results in forcing the generation of steam, but it is not strictly in the class of burning pulverized coal in suspension and does not possess the same range of possibilities.

Coarsely pulverized coal has the redeeming quality of damping the temperature of the furnace and may be resorted to for the purpose of cooling overheated hearths without chilling; nevertheless, pulverized coal larger than the 80-mesh grade should be avoided in ordinary operation for best results. A uniform mixture averaging 100 per cent 150-mesh or finer should be employed, especially in the case of low-grade coals.

Pulverizing mills ordinarily produce powder of the cement-mill standard, and on the basis of fairly dry coal the average cost of pulverizing runs from 15 to 30 cents per ton ground at the rate of 2 1/2 to 1/4 tons per hour, respectively.

Qualities Desirable in Coals to be Used in Pulverized Form

In burning pulverized coal there is no restriction on the variations in quality found in commercial grades. Low-grade coals perform better than high-grade on account of the large proportion of impurities they contain, resulting in less destructive temperatures and thereby in lower combustion losses. Generally it is necessary to dilute with air the gases resulting from the combustion before they are used, but less dilution is required with low-grade coals and in consequence more economical operation is obtained through their use.

A large proportion of volatile matter has heretofore been regarded as a leading requirement for pulverized fuel on account of its combustibility, but experience does not support this; on the contrary, there are those who consider it expedient and beneficial to drive off a portion of the gaseous content of a coal before burning it.

The temperatures of combustion hearths for pulverized coal range from 2200 to 3000 deg. fahr. depending on the design of furnace, the service, and the fusibility of ash and refractories employed. With these temperatures predominating the deflagration of all commercial coals is assured, and the restriction on any particular kind of coal for powdered fuel on account of combustibility is eliminated.

The suitability of coal for use as powdered fuel is to be gaged by its pulverizing qualities, and the soft grades, which incidentally contain a large proportion of volatiles, are to be preferred. Hard coals and coke are very severe on the mills. For pulverizing, slack coal and all small sizes under 3/4 in. are desirable in that they eliminate the necessity of crushing. Screenings, which usually are fragments of the more combustible portions of coal, are excellent for pulverizing on account of the lesser amount of impurities present.

Uniformity in the quality of pulverized coal is as essential as uniformity in the fineness of the powder, and for continuous reliable service as essential as its calorific value. In preparing the powder it is extremely important to mix and blend the coal so as to uniformly distribute its impurities. The ill effects of the irregular presence of impurities are felt more as the quantity of fuel burned becomes smaller. When burned in large quantities—necessitating larger combustion space—there is a chance for equalizing the variations of the impurities. To obtain a uniform quality of fuel wherever the coal supply is of varying kind the various grades of coal may be blended to advantage by pulverizing, thereby effecting economies which might not otherwise be realized.

Effect of Moisture in Coal

Moisture in coal is objectionable not so much on account of the apparent thermal losses but because it renders pulverization difficult and more costly. For this operation 5 per cent moisture may be regarded as the permissible limit, and air-dried coal is entirely satisfactory for the efficient operation of the mills. However, in cases where the storage of pulverized fuel is necessary, coal should not contain more than 1.5 per cent moisture as a greater amount tends to cake the powder, and in the event of iron pyrites being present, their oxidation by water may be the origin of spontaneous combustion. It has also been considered necessary to dry the coal before grinding and experience has shown that this practice brings about losses of volatile combustible and adds from 8 to 12 cents per ton to the cost of preparation. Furthermore, with reasonably protected storage and handling facilities it is possible to render the raw coal sufficiently dry, thus doing away with the separate drying operation. The present tendency in drying coal is to confine this process to central distribution plants, such as will be required for railroad or large service. For stationary work, self-contained pulverizing units in which grinding, air mixing, and feeding of the combustible mixture directly to the furnaces are progressively accomplished are more desirable, especially so since preheated air—a by-product of the furnace—can be used in their operation, thereby conditioning the mixture for better combustion performance.

In the combustion of pulverized coal a certain amount of moisture is beneficial rather than detrimental in that it tends to maintain the temperature of combustion constant and thereby renders deflagration more steady. The explanation of this effect is that the normal temperature of dissociation of the solid particles of coal is greater than that of water, and in the process of combustion some of the moisture that may be introduced with the charge breaks up, absorbing thermal energy and thereby lowering the combustion temperature.

Powdered coal containing as much as 15 per cent of moisture has been burned satisfactorily.[1] This amount is no doubt excessive, but by introducing preheated air for combustion through the self-contained pulverizing units or otherwise it is possible to absorb large proportions of moisture from coal and use this to advantage in the process of combustion.

Ash—Sulphur—Spontaneous Combustion

The ash resulting from burning solid fuels has been and always will be a problem for each particular case. With pulverized coal the ash from particles consumed in suspension is a light powder. This powder is carried along with the gases and deposited on all surfaces beyond the hearth, making removal more or less difficult. In the case of boilers this kind of ash accumulates on the tubes, lessening the evaporating efficiency and necessitating periodical removal by steam or air sprays. The dissemination of this ash can be somewhat reduced by proportioning the combustion space so that after combustion is completed the gases expand rapidly, decreasing their velocity and density and depositing the ash particles in a suitably located pit. If the powder is too coarse, or the amount of fuel injected into the hearth is greater than can be fully consumed therein, the coal particles while in the distillation stage are impelled against the walls and there coke. The continuous supply of these unconsumed particles builds up and burns slowly, leaving ash of a pumice-stone formation, which, if in the proximity of the zone of deflagration, slags and becomes very difficult of removal. The remedy for this is the continuous production of uniformly fine powdered fuel and the proper design of the combustion space to consume completely all the particles of the fuel charge.

On the whole, compared with lump-coal burning on grates,

[1] Firing Boilers with Pulverized Coal (Henry Phipps Plant), W. S. Worth, *Power*, vol. 33 (1911), pp. 267-269.

experience shows that with reasonable precaution ash from pulverized coal is less troublesome in every way. Slagging of the ash and brickwork occurs only when these are too near the deflagration zone, which naturally is several hundred degrees higher in the temperature than their fusion points. This difficulty is eliminated by designing the combustion hearth so that the side walls and top arch attain a temperature lower than the slagging point and the bottom is no higher than about 2000 deg. fahr., which avoids melting of the low-fusible ash.

The presence of sulphur is to be looked upon with less concern in the case of pulverized coal, since, as mentioned before, the high temperatures attending the combustion of this fuel dissociate water into its elements and hold these in a condition less liable to combine with sulphur. Pulverized coal containing over 5 per cent sulphur has been used in boiler settings without giving evidence of corrosion.

In regard to safety, it may be said that while mine explosions attributed to coal dust indicate its combustibility and the testing station of the U. S. Bureau of Mines in Pittsburgh has painstakingly shown that coal dust in suspension can be made to explode, pulverized coal, nevertheless, is an excellent fire extinguisher. To ignite it in any form, coal must be brought to the temperature of its ignition, 1000 deg. fahr. and above. This is greatly in favor of pulverized coal since it permits its being conditioned for better combustion performance by heated air before using.

Importance of Preheating Combustion Air

Combustion air for pulverized coal has variously been applied under different pressures and usually at ordinary temperatures. No judgment has yet been passed on the condition of the necessary air bearing either on the flame-propagation qualities of powdered coal or on the dimensions of the combustion chamber, and in the absence of definite experimental data one conjecture is as good as another. Although the relatively low deflagrability of the powder suggests it, it is only through costly experience that we have learned the advantage of low air pressures and velocities for combustible mixtures.

The function of air in connection with burning pulverized coal is not only to provide the proper amount of oxygen to hold and convey the powder or supply a dilution element, but also to carry the flame—zone of oxidation—in suspension throughout its path; that is, away from the brick walls. The importance of this requirement is obvious, in that it eliminates destructive temperatures and the accumulation of ash and semi-burnt particles on the brick walls, and secures more perfect burning of the fuel particles "in suspension".

The value of heated air for mixing and dilution purposes cannot be overestimated. It prepares the fuel for quicker deflagration, thereby permitting a larger quantity of fuel being burned in a given space, it maintains the powder in better state of separation, and in general promotes steadier combustion. Furthermore, in conjunction with a suitably designed furnace it is possible to attain a better heat balance by utilizing waste gases and radiation for heating the combustion air required for the treatment of the powder.

For mixing purposes the air temperature should not exceed that of the coking point of the particular coal used, and for dilution the higher the temperature of the air the better.

Comparative tests on a 250-hp. boiler using combustion air at 65 deg. fahr. and 750 deg. fahr. with powdered bituminous coal showed that, other things being equal, with air at 65 deg. the evaporation was 7.7 lb. per lb. of fuel and the temperature of escaping gases 528 deg., while with the 750-deg. air the evaporation was 9.17 lb. per lb fuel and the temperature of the escaping gases 475 deg. On the basis of the normal boiler rating this performance indicated a gain of 15 per cent. with hot air and a loss of 12.2 per cent with air at the ordinary temperature.[1]

At the present time air pressures from 0.5 oz. for small furnaces to 10 oz. and above for cement kilns are being used with success, while pressures of 3 oz. and under for boilers have given good results. As mentioned above, pulverized coal should be burned in suspension and with excess air on account of the high temperatures that develop in its combustion (see Table 1). The pressure and distribution of the air necessary to secure this condition vary with each case and demand careful consideration to obtain best results.

In general, the finer the powder and the warmer the air the lower will be the pressure necessary to inject the combustible mixture into the furnace, and the better will the powder be held in suspension; also, other things being equal, the larger the amount of fuel that can be burned in a given space. This implies lower furnace losses.

Comparison of Stoker and Pulverized-Fuel Plants

Economy in connection with fuels is a term which must be used with caution and depends upon the purpose for which fuels are employed. If pyrometric effects are sought, as in metallurgical furnaces, the conditions and rate of burning fuel are such that thermal efficiency is out of the question and economy can only be expressed directly in dollars, regardless of the kind of fuel used and its performance. If calorific or straight heating effects are desired, as in steam generation, thermal efficiency plays the all-important part, and in this connection two factors are to be considered: one involving the furnace performance and combustion losses, and the other the means provided to absorb the thermal charge in the products of combustion. These two conditions go hand in hand, and maximum economy is therefore a function of the two.

With pulverized coal the furnace and combustion losses can be greatly decreased as compared with those incurred in burning lump coal over grates, by reason of its manner of burning, and it is to that condition alone that very acceptable fuel economies can be effected by its use. Instances are recorded showing that 10,500-B.t.u. coal fired as powder in a given boiler setting has evaporated a larger amount of water than 12,090-B.t.u. coal fired by hand.[1] Invariably records of tests made in steam plants of various capacities using pulverized coal as fuel indicate boiler thermal efficiencies of 75 to 80 per cent and over, which parallel the best efficiencies obtainable with modern stokers in large installations. The consensus of opinion is that with the better methods of firing pulverized coal the high efficiencies observed both in the hearth and in the boiler remain fairly constant throughout a wide range of quantities of fuel burned, whereas with stokers, which permit only a rigid design of combustion hearth, beginning with the higher efficiencies in large boiler installations the efficiencies drop as the installations become smaller. This is self-evident in part, since in stoker practice only the better coals can be used to advantage and a certain amount of fuel loss cannot be prevented, whereas by pulverizing, all grades of commercial coals are admitted to the same service with equal merits and fuel losses may be avoided. And since deflagration, and therefore the combustion space necessary, becomes a measure of the actual amount of combustible present in the coal, the hearth losses remain practically constant for all conditions encountered in actual service.

The conclusion to be derived is that, other things being equal, the competition between the use of pulverized-coal firing and stokers for large boiler plants will be a matter of flexibility of service, convenience in operating, and maintenance cost; while in small plants fuel economy will be the deciding feature along with the other advantages, and pulverized coal will obtain the preference, not only on the basis of combined first and operating costs, but especially so after the greater convenience and flexibility of service resulting from its use have been sufficiently demonstrated.

Conclusive figures on the operating and maintenance costs of pulverizing equipment have not yet been obtained from actual practice, since no specific standards have been established. With

[1] J. H. Travis, *Power*, vol. 24, pp. 168-196 and 271.

[1] G. F. Gasbe, *Railroad Gazette*, vol. 34.

self-contained pulverizing units, however, it is thought that, totalizing all the items of expense, the operating costs of an equivalent stoker equipment are approximately the same.

Considered as a gas, pulverized coal when mixed with 100 per cent of combustion air produces a fuel mixture having a calorific value of from 90 to 120 B.t.u. per cu. ft. Fig. 1 gives the relative costs of fuels on the basis of their calorific values.

Where it is desired to determine the maximum price which could be paid for a low-grade coal for pulverizing to place it on a basis comparable with higher-grade fuel for stoker firing, the formula

$$P_1 = \frac{P_2 H_1 E_1}{H_2 E_2}$$

may be used, in which P_1, P_2 = price per ton, delivered, dollars; H_1, H_2 = B.t.u. per lb. of coal; E_1, E_2 = combined boiler efficiency; and the subscripts 1 and 2 refer respectively to low-grade and high-grade fuels. The price P_1, however, does not include the cost of pulverizing.

Burners

Under the name of "burners" the devices that have been used to mix the necessary air and coal powder and feed the mixture to the hearth are numerous. Their merits are relative at best and each has its limitations, their only function being to convey, mix thoroughly and deliver the fuel charge to the hearth in the required quantity. Much ingenuity has been exhibited in the development of these devices, but little attention has been paid to what is more essential, namely, the correct design of the furnace for burning the combustible mixture.

Fig. 2 illustrates diagramatically the schemes generally employed in the devices now used. Scheme 1 shows a device which depends entirely on the induced chimney draft for the air supply. Naturally its capacity is limited by the chimney draft and its regulation is restricted to a small margin. This method would be suitable for service in which steadiness is a minor consideration. Scheme 2 shows a combination of natural and forced draft which permits wider application than Scheme 1; its regulating features are better, but it is still subject to the fluctuations of the natural draft. Scheme 3 shows an arrangement which affords full control of the fuel and the air, and in consequence greater flexibility in its operations, being less affected by external variables. It lends itself admirably to the application of

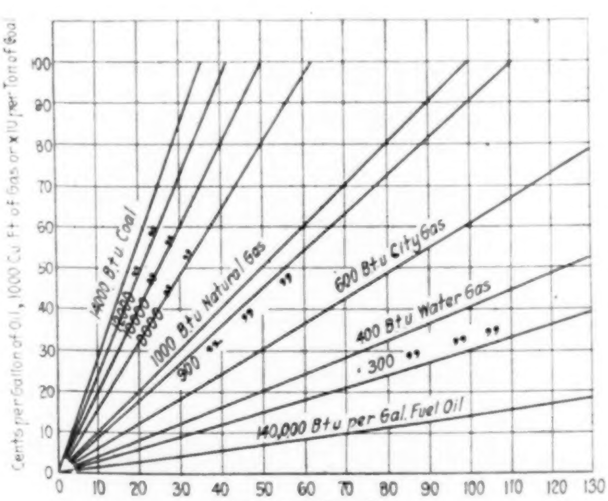

FIG. 1 RELATIVE COST OF FUELS

heated air for combustion through the secondary blower *f*, a method which should be adopted exclusively for burning pulverized coal. It also makes it possible to automatically control the fire in response to varying load conditions, something particularly desirable in steam generation. Schemes 4 and 5 illustrate arrangements in which self-contained pulverizing units are employed, simultaneously preparing and feeding the fuel to the hearth. These machines are usually provided with a fan for the double purpose of separating the powder in the process of grinding, and mixing and supplying part or all of the combustion air. Schemes 3 and 5 possess the same merits as to flexibility, regulation and usefulness and should be adopted wherever possible.

Equipment for Preparing Pulverized Coal

Two distinct methods are in use to prepare pulverized coal. One of these involves a plant in which the fuel is treated independently of the rate of its consumption and comprises, beginning with the coal bunker and in the order of the operations: crushers, crushed-coal hoppers, driers, magnetic separators, pulverizers, powdered-coal storage hoppers, distributing conveyor feeding individual hoppers at each furnace which are fitted with feeding devices, and a blower or separate blowers operating in conjunction with the feeding devices to mix and feed the fuel to the furnaces. This various equipment is interconnected with suitable elevating or conveying means to conveniently carry out the cycle of operations and permit of multiple arrangements to suit local conditions. The advantages of pulverizing plants are:

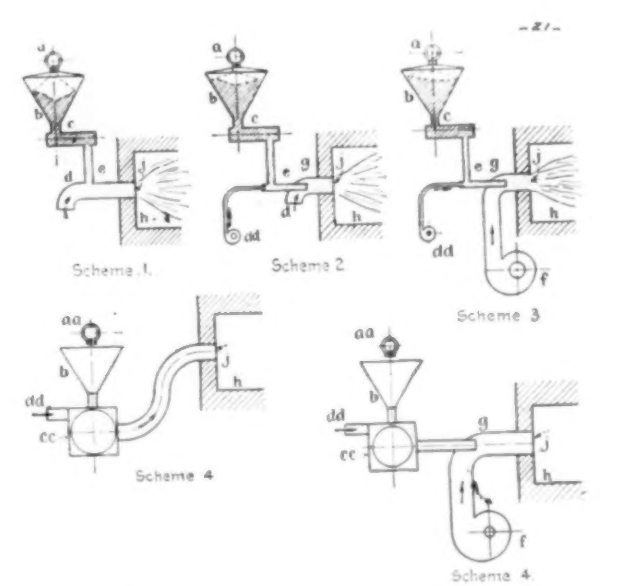

FIG. 2 PULVERIZED-COAL FEEDING DEVICES

a, Screw conveyor for pulverized coal; *aa*, Screw conveyor for crushed coal; *b*, Hopper; *c*, Feeding device; *cc*, Self-contained pulverizing, mixing and feeding machine; *d*, Induced-draft combustion air; *dd*, Primary mixing air blower; *e*, Primary mixing chamber; *f*, Secondary air blower; *g*, Secondary mixing chamber; *h*, Hearth; *j*, Nozzle. The delivery outlet or outlets are arranged and shaped to suit the hearth, which in turn depends on the nature of the service.

a Uniformity in the quality of the powder
b Ample fuel supply to provide for varying loads and starting without taxing the normal operation of the equipment
c Suitability for large installations where uniform service and a central point of distribution are necessary.

The disadvantages are:

a High first and operating costs
b Large floor space required
c Multiplicity of equipment and parts.

The other method employs self-contained pulverizing units, conveniently located near the point of fuel consumption, which prepare the powder as required. Beginning with the coal bunker, the equipment comprises: crushers, magnetic separators, crushed-coal storage hoppers, distributing conveyor feeding individual hoppers at the pulverizers, pulverizers, blower for combustion air, and feeding devices leading to the furnaces. In the event of a single pulverizer feeding finished fuel to various furnaces the conveyor is eliminated, the distribution being accomplished by air as a part of the feeding devices for the furnace.

The advantages of this arrangement are:

a Simplicity of equipment and therefore low first and operating costs
b Individual control of each furnace
c Adaptability to existing plants
d Good regulation without altering the quality of the powder.

The disadvantages are:

a Necessity of carrying spare units, on account of severe wear and tear when in continuous service
b Absence of storage of powder for starting.

As a general proposition, if conditions permit ample storage and suitable handling facilities to air-dry and mix the raw coal thoroughly, the self-contained equipment offers greater possibilities both in flexibility of service and arrangement and economy.

II FLAMES[1]

The flame resulting from the deflagration of pulverized coal differs from that of other fuels in the larger combustion space required on account of its low combustibility, and the higher temperature due to the rapid breaking up of the solid structure of the coal particles.

In general, the more inflammable the material or the lower the rate of oxidation, the smaller the space required for its combustion and the lower the average temperature that develops.

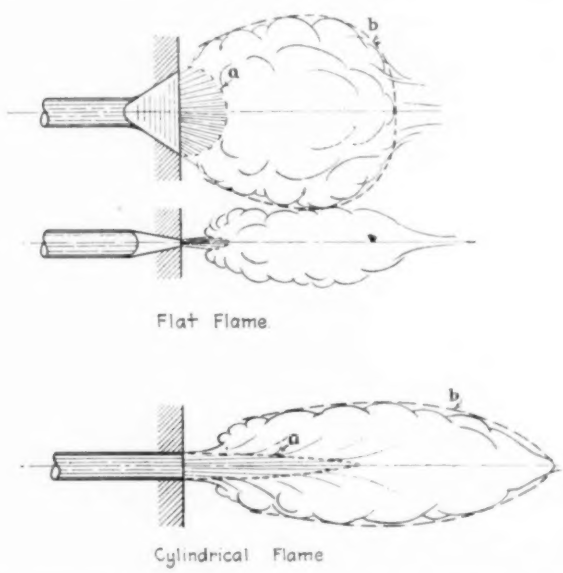

Fig. 3 Approximate Shapes of Flat and Cylindrical Flames of the Same Capacity and Under Similar Conditions

a, Zone of initial oxidation; *b*, Zone of complete oxidation. Note the length of zone *a* in the cylindrical flame. Coking of powder has been observed to take place within this zone through baking.

This condition is shown by the performance of explosives and the slow burning of gas, oxidation of iron, etc. The average temperature of combustion of gases in ordinary air is from 1500 to 2000 deg. fahr., and, for a given amount of fuel consumed, the combustion takes place in a smaller space than that required for atomized oils, which begin to burn steadily at about 2000 deg. Experience shows that the deflagration of pulverized coal requires a still larger space and that the average temperatures developed by its combustion are much higher—2500 deg. and above.

Fuels are rendered more inflammable as they are brought to or carried beyond their ignition temperature and are more thoroughly mixed with the necessary oxygen.

[1] Flame is usually defined as the luminous or visible portion of the zone of deflagration. While this is the ordinary conception, in the present case by "flame" is meant the zone of oxidation, that is, the space within which the oxidation of the combustible elements is completed, which is much larger than the luminous zone, especially in the case of blast flames, such as obtain with oil, gas and pulverized coal.

Temperature a Measure of Relative Molecular Activity

Temperature, like voltage and pressure, is a difference of potential and, with reference to burning fuels and heating, is a measure of the relative molecular activity of the materials involved, which can be expressed quantitatively in terms of MV^2. Reference to this phase of the dynamic theory of the formation of matter is made here merely to indicate the fundamental relationship between temperature, mass and the performance of the component material particles; so that for a given mass the measure (temperature) of thermal energy varies as the square of the molecular activity.

The truth of this is evidenced in part by the fact that the specific heat of a substance increases with the temperature, though not in proportion thereto, and in a manner which confirms the law just stated. A long metal bar heated at one end up to melting point is another example showing similar temperature conditions at equal distances apart toward the cold end.

As yet no definite methods have been found to measure thermal energy in terms of MV^2, and for the time being the practical value of the conception of that law lies in the aid it lends in following the actions that take place during combustion and heating to determine with some precision truer thermal conditions and effects that may result.

Assuming then that temperature is a function of the square of the activity of the particles of matter, it is easily conceivable that the greater the molecular or atomic disturbance caused by the combination of oxygen and the combustible elements, the higher will be the temperature of combustion, and that this temperature, though not directly proportional to, will vary as some function of the square of the rate of combination. If we then assign a constant value to the unit increment designated to measure temperature, as our present degrees, the heating of any given mass will vary as some function of the square root of the applied temperature (the temperature difference between the heating medium and the mass to be heated), and inversely as the mass. That is, the heating is not directly proportional to the temperature applied as is ordinarily understood. This fact is conspicuously verified in metallurgical work where a wide range of temperatures obtains.

The influence of mass, however, is not a constant one, since the nature of its structure varies in all materials and this condition must be looked to for the inconsistent results ordinarily observed in all heating operations. But a practical solution of the difficulty is not out of reach, for it may be stated that within the range of temperatures employed in industrial applications, manifestations akin to resistance, inductance and capacity appear in the process of heating, and that it is consequently possible to develop and introduce a term of the order of "power factor" to designate more precisely the amount of useful thermal energy from any one reaction, thereby eliminating prevalent empirical considerations. This method of dealing with the subject of burning fuels and heating in general, however, in the absence of conventional definitions and sufficient experimental data to quantitatively confirm the law, naturally calls for a more technical treatment. For the purpose in hand, however, it is necessary to adhere to existing methods and units, except that we have at our command a more comprehensive conception of the actions that take place, which is a material aid in arriving at practical results.

Coals Should Be Rendered Equally Deflagrable

Profiting by the foregoing considerations and recognizing that the structure of coal chemically and physically is a variable one, the all-important requisite for pulverized coal is that its nature shall be rendered as uniform as possible with reference to a given standard, so that for any given furnace the temperature and operating conditions at the hearth shall be maintained as constant as possible with the various kinds of commercial coals and afford approximately the same regulating qualities.

Assuming a continuous production of powder of uniform fineness and impurities, the inherent weakness of coal for burning

in powdered form is its deflagrability, which varies as its structure varies. It is possible, however, to alter the structure of all coals pyrometrically so they acquire a sufficiently uniform texture before combustion to practically satisfy the requirements. In general, hard and high-ash coals should be heated to a higher temperature than soft and low-ash coals, the coking point of the particular coal being the limit.

By rendering all grades of coal equally deflagrable the precision of other requirements becomes apparent: (*a*) The velocity of the fuel-mixture feed is limited and fixed by the velocity of the flame propagation, which means constant pressure and supply of air for all grades of coals, measurable by the actual amount of combustible content; (*b*) wider regulation by direct fuel control is possible; (*c*) very steady lower hearth temperatures can be secured. The desirability of these conditions is obvious. In general, for constant results the more inflammable the fuel mixture the higher the velocity of discharge and the lower the temperature of the hearth; and conversely, the less inflammable the fuel mixture the lower the velocity of discharge and the higher the temperature of the combustion hearth necessary to burn the same amount of fuel in a given space. For the realization of these conditions it is assumed that the distribution of combustible charge over the hearth is the same in each case.

Proper Velocity for Fuel Mixture

The proper velocity for the fuel mixture as determined by its inflammability can only be found by trial, and the condition to be fulfilled is that the base of the flame shall approach the outlet as closely as possible. A lower velocity may result in backfiring within the feed tubes, which are of appreciable dimensions, and cause a more or less destructive explosion. A higher velocity carries the mixture too far into the hearth before com-

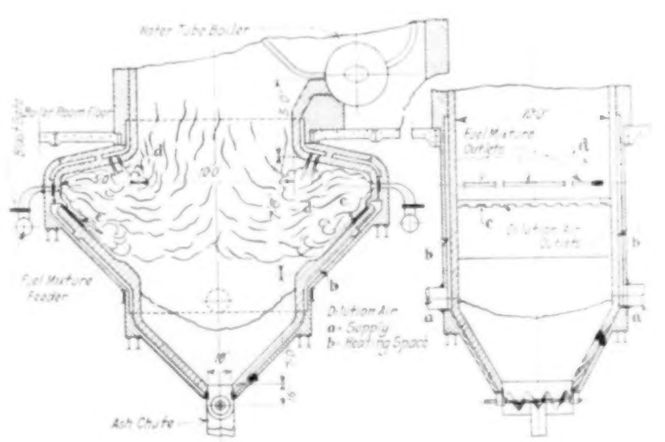

FIG. 4 GENERAL DESIGN OF FURNACE FOR BURNING ALL GRADES OF COMMERCIAL COALS IN PULVERIZED FORM UNDER A WATER-TUBE BOILER

bustion begins, and has the effect of coking and consolidating the particles, which drop to the bottom of the hearth in the form of relatively large globules, thereby causing faulty combustion and loss of fuel. Coking of the combustible charge is very perceptible in connection with discharge outlets of large diameter such as are used in cement kilns. The action in this case has been attributed to more rapid combustion on the surface of the combustible jet, which has the effect of baking the core within (see Fig. 3). This difficulty has been overcome by using outlets in the form of a slot of the required cross-section, thereby exposing more surface to the hot gases in the hearth.

Volume of Flame or Zone of Oxidation

The volume of the flame, that is, the zone of oxidation, in general, cannot be predetermined on account of the many uncontrollable variables, and especially because the virtual temperature of combustion cannot be ascertained by present means and the real time element of complete oxidation is not definitely known. Observation and analysis show that, under similar conditions, more inflammable fuels burn with a shorter flame than the less inflammable. In connection with pulverized coal the problem becomes more complex on account of the variable amount of excess air required for its combustion. The values for this excess hitherto suggested vary widely and are so conflicting as to preclude their use. Nevertheless, based on the average temperatures of combustion and the amount and temperature of the gases required, it is possible to arrive at a very satisfactory conclusion regarding the dimensions for the combustion and gas space.

Briefly, though in the combustion of pulverized coal there is a wide margin for regulation by judiciously applying the conditions herein indicated, nevertheless, until more complete ex-

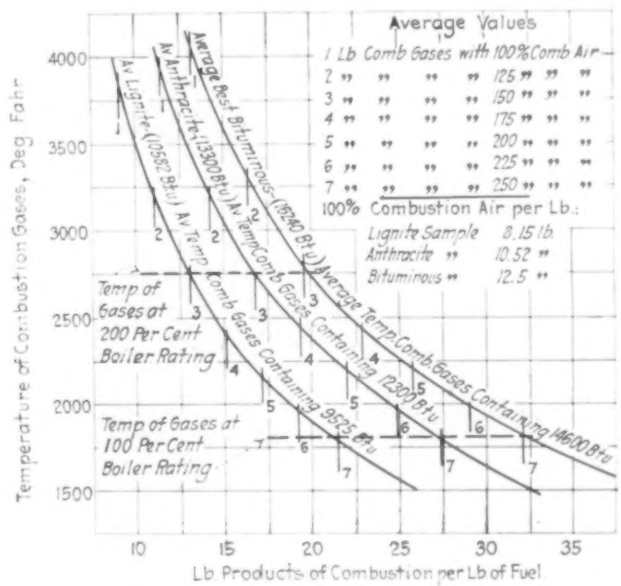

FIG. 5 GASES OF COMBUSTION OF TYPICAL COALS AND THEIR AVERAGE TEMPERATURES

perimental data are available, it is necessary to consider every element entering—from the nature of the coal to the performance of the boiler—and to disregard all precedent existing in the burning of lump coal in order to secure satisfactory results with the powdered fuel.

III FURNACES

Although in general furnaces are more or less special structures and their character is determined by the service they perform, their design and type of construction depend chiefly on the nature of the fuels used in their operation.

The combustion of a fuel results in gases charged with the available useful heat developed during their formation, and ash, in the case of fuels containing solid impurities. The quantity of gases and their temperature depend on the quality of the fuel and the amount of air used for combustion and dilution purposes, which can be varied to suit practical requirements.

In steam-boiler settings the duty of both boiler and furnace is a calorific one, that is, one of straight heating, and is measured by the amount of water evaporated in the boiler by the combustion gases from one pound of fuel.

The amount of water that can be evaporated in any type of boiler by a given quantity of fuel depends on the quality of the steam desired and the ability of the boiler to absorb the heat charge of the gases supplied by the furnace necessary for the generation of the steam required. So that, briefly stated, the boiler is subordinate to the steam requirements and the furnace

(*Continued on page 787*)

Fuel Saving in Industrial Plants

By JOHN F. TINSLEY,[1] WORCESTER, MASS.

Although war-time necessity of saving fuel has happily passed, the conservation of fuel is still as important as ever. During the war the industries of New England benefited in many ways through the suggestions and assistance of Fuel Conservation Committees, and although these are now of the past, their work is still having its effect. Their methods and the recommendations which they made are of value even today and this paper which outlines the campaign of the Worcester Fuel Conservation Committee contains a brief account of the manner in which that committee dealt with the problem.

AFTER the very strenuous winter of 1917, with its distressing "heatless" days and other comfortless evidences significant of a fuel shortage in New England, Massachusetts awakened to a fuller appreciation of the importance of conserving fuel, if her industries were to do the part expected of them in the winning of the war. Under the excellent guidance of the state and local fuel administrations, steps were taken in the early spring of 1918 to point out to the industrial fuel users of Worcester the critical situation that was likely to exist the following winter, and to create an organization that would carry out the work successfully and effectively.

The two things necessary to the accomplishment of any big work—incentive and organization—were quickly apparent, the former through the daily news columns of those dark days when the last great German drive was on, and the latter through the splendid response that has been so characteristic of the people of Worcester in every phase of war activity. At the time of the signing of the armistice, in November, the fuel-saving campaign had been successfully under way for several months with gratifying results and with every indication of an accomplishment in the saving of fuel that would exceed our expectations. But within a short time after that event the committee ceased its official functions, and this paper therefore deals with the work done in a comparatively few months prior to the close of the war.

The work of organizing Worcester's fuel-saving campaign was started in May 1918 with the appointment by the local fuel committee of a Factory Fuel Conservation Committee, consisting of three men selected from the management of three of Worcester's industries. This committee soon realized there were two distinct steps vital to success: First, that the managing heads of the various plants should be aroused to a full appreciation of the critical situation likely to exist in connection with the fuel supply; and second, that the foremen and workmen throughout the factories should be brought to feel that, after all, the real success or failure in meeting the problem rested in large measure with them.

The first part of the committee's program was easily and quickly accomplished. In a series of meetings the plant managers generously pledged their support and coöperation, and by so doing enabled us to vigorously take up the second step with the employees in the various plants. This task, however, was a large one, since it involved not only arousing the interest of upward of 75,000 men in about 260 plants, but also required for effective results that this interest be maintained.

To this end the Factory Fuel Conservation Committee appointed a sub-committee to assist in the work. This sub-committee was composed of practical engineers who could carry the message right to the workmen themselves. It was made up of eleven men chosen from the leading industries of Worcester, and the results accomplished through their fine work proved clearly the wisdom of their selection. Several of these men were technically trained, and all were practical. They were all engaged at the time of their appointment in active engineering work in the various concerns with which they were connected. These men were selected because the fuel problem has been for some time past a greater one with the larger plants than with the smaller ones, and many steps had already been taken by the larger concerns to save fuel. Consequently, through these engineers we wanted to pass along the full advantage of such experience to others.

The next step was to get the various shops organized. The State Fuel Administrator had requested that each factory appoint a Factory Fuel Committee, and the managers of the various industrial plants signed pledge cards agreeing that they would have fuel committees promptly appointed in their plants. Thus we had in a short time fuel committees appointed by factory managements to the number of 258 in Worcester. Some of those committees contained in the case of the smaller plants one man, but in the larger plants several men, who only represented the various lines of work in which fuel economies were possible. More than a thousand men were thus actively organized in Worcester on fuel-saving committees.

This portion of our organization was very effective, and the response on the part of these men whose efforts were exerted among thousands of workmen in Worcester was splendid. The details of factory organization and personnel thereof were left in most cases to factory managements, as we wanted these committees to feel that the responsibility was primarily with them. In this connection it is interesting to note that those plants that accomplished the most specialized in their factory organization to the extent of having specific men for specific jobs.

With an organization thus created that could easily reach the men in the shop, we were ready for business. As the problem was to save fuel, it was necessary at the outset to see that the various factory fuel committees understood the seriousness of the fuel situation, that they were organized to do effective work, and that in every plant the best opportunities for making economies were pointed out and thereafter followed vigorously. To accomplish these objects the various factories, to the number of about 260, were assigned to the Engineers' Committee for inspection, instruction and supervision. Each engineer was given about 25 plants to look after, assignments being made in groups throughout the city to facilitate visiting, though in certain cases all the plants of the same general manufacturing character were grouped together under one engineer.

In a remarkably short time, due to the splendid enthusiasm of these engineers and the generous coöperation of their employers in allowing them the time necessary to do this work, all the factories in the city were visited, the factory committees instructed, and an initial inspection made by the engineers. At the same time those lines offering the best promise were carefully pointed out to each factory committee, and practical suggestions made to meet the needs in each case.

There was one feature of our campaign on which we laid special emphasis. There is likely to be an impression in the average plant that the place to save fuel is where the fuel is used—in the boiler room. In fact, very little organized effort has been made in the past to save fuel anywhere else. There are, of course, many opportunities for saving fuel by efficient firing and by good boiler-room methods, but there is also a large field for fuel economies beyond the boiler room. The boiler room must meet the demands made upon it, and that demand is created outside. It was therefore apparent that if we were to make a favorable showing, the greatest opportunity for so doing was essentially outside of the fire room, and the economies in the fire room would necessarily have to be limited to such matters as could be effected quickly and without radical changes.

The visits and inspections of the engineers gained from every plant the best of coöperation from the start. The instances were few where any pressure had to be exercised to obtain results. In connection with the work certain records and statistics were, of

Abstract of paper presented at a meeting of the Worcester Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, May 28, 1919.

[1] Chairman, Worcester Fuel Conservation Committee.

course, necessary. We established for every plant monthly reports of fuel used, as compared with corresponding months of previous years, and also sufficient statistics as to operating schedules to permit of comparisons being made.

Inspection reports covering specifically all recommendations were also made. On the second and succeeding visits a report was rendered as to previous recommendations put into force, and additional suggestions offered. These reports were for two purposes: first, to give the State and local fuel committees reliable information (the fuel authorities took the position that in case of a critical shortage of fuel it was probable that the allotment of fuel to any plant would depend on the degree of coöperation that was extended by it); and second, to show the factory fuel committees that they were being rated on actual performances and compared with other plants.

Some idea of the value of these visits may be obtained from the records of recommendations made by the engineers. As a result of a single visit to 117 of the larger plants, 547 recommendations were made, or an average of about five per plant. Of these about 85 per cent were carried out before the second and third inspections, a response speaking most eloquently of the fine spirit of coöperation with which our efforts were met.

A few typical recommendations follow:

1 Many unnecessary lights are kept burning. Get everybody to help the cause by turning off unnecessary lights
2 Your belts are not looked after closely enough. You are losing power and money by having belts both too tight and too loose
3 Your motors are underloaded. The loss in efficiency and power is large if your motors run much underload
4 Your shafting should be lined up. Friction load in the average plant is very high, and power is wasted at a terrific rate if shafting is out of line
5 You have a lot of uncovered high-pressure steam pipes. Your losses are high, due to this cause
6 You have many machines running idle and wasting power. Install belt hooks and slip the belts off on machine shut down for long periods. If for short periods, educate your men to shift to loose pulley
7 Fix your doors and windows to prevent undue loss of heat
8 Wash your windows. You have an opportunity to save at least ½ hour of lighting daily by so doing.
9 Your fire-room practice should be improved. Keep fires bright, fire frequently, avoid holes, clean regularly, keep ashpit cleaned out, clean tubes oftener, get better damper regulation, etc.
10 Indicate your engine. We will help you take the card and interpret it.

There were, of course, many others, but all were of the commonsense variety, and it is evident that if all the industrial plants in any community worked concertedly and continuously along these lines, an economy in fuel must of necessity result. Furthermore, the service on the part of the engineers was not merely advice, for often they supplied from their own companies testing instruments, shaft-lining instruments, engine-indicating apparatus, etc., and assisted in making flue-gas analyses, engine indications, etc.

Aside of the work done in connection with the engineers' visits and inspections, the committee also felt that the educational or propaganda side should be emphasized. Literature that could be understood by the average workman relative to all phases of the fuel-economy problem was obtained and was distributed to the various factory committees. To firemen and engineers were issued short pamphlets covering in the simplest terms the fundamentals of economy as far as the generation and application of power were concerned, while to master mechanics and electricians were directed bulletins on belt troubles, power-transmission losses, etc.

We found the language most effective was that which dealt with dollars or tons of coal. The coöperation of a workman in regard to turning off an electric light was forthcoming much more quickly when he learned that, small as it was, in a year's useless burning it consumed several hundred pounds of fuel, and that 100 ft. of 1-in. uncovered pipe conveying live steam at 100 lb. pressure wasted upward of $100 worth of fuel per year, with coal at $7.50 per ton.

In addition to this service, the Factory Fuel Conservation Committee issued for two months a monthly newspaper or news letter which was much appreciated. In this paper were published the names of all factory-committee chairmen—something which was apparently liked—and a number of short, pithy, readable paragraphs giving suggestions for fuel saving. Efforts were made to cover all phases of the subject and thus interest engineers and firemen, master mechanics and electricians, as well as the rank and file of the workmen themselves. A noteworthy feature of this paper was the publishing under the various firms' names of the several steps taken by them to save fuel. This served an admirable purpose in stimulating a spirit of friendly rivalry, and also served to disseminate generally a knowledge of fuel-saving methods that could profitably be followed by other plants than those under which they happened to be reported. In a word, our educational or propaganda service was intended to give all industrial fuel users a knowledge of "what the other fellow was doing."

And now the results. Table 1 gives a comparison between the average monthly coal consumption of 13 of the leading industries in Worcester as between 1917 and 1918. The months under comparison are those of the late summer and early fall. The plants represented include the wire, grinding-wheel, belting, crankshaft, machine-screw, machine-tool and carpet industries, as well as one large public utility.

TABLE 1 AVERAGE MONTHLY BITUMINOUS COAL SAVING

Plant No.	Number of months included in average	Tons of coal consumed in 1917	Tons of coal consumed in 1918
1	3	16,953	14,778
2	3	7,847	7,044
3	3	1,697	1,438
4	3	1,303	1,388
5	3	866	908
6	3	586	200
7	3	367	340
8	3	333	350
9	3	296	144
10	3	293	189
11	2	278	200
12	2	255	15
13	3	132	110
Total		31,232	27,104

The table indicates a general reduction in coal consumption in 1918 of over 13 per cent when compared with the same months of the previous year. There is another interesting point about this table. If it were divided into two parts of six plants each, representing the larger coal-using plants separate from the smaller ones (eliminating plant No. 12 which shows the largest relative variation), the saving is 11.9 per cent for the group of large coal users, as against 21.6 per cent for the group of smaller users. This is apparently as we should expect. The larger coal users had been studying their fuel consumption previously, while in the smaller plants the matter of fuel naturally had not been so prominent a matter of cost with them.

The question will naturally arise in connection with the comparison as given in the table as to whether it represents in both years similar operating capacities. In other words, was the load of these plants as large in 1918 as in 1917? This is an exceedingly difficult matter to determine, but a fair idea of the operating load of the plants may be obtained from the number of employees represented in these concerns in 1917 and 1918 at the time the comparisons are made. The twenty-six concerns included in the two lists report for 1917 at the time the comparison was made approximately 20,200 employees, and in the corresponding months of 1918 these same companies reported an approximate number of employees of 20,350, that is, an increase of approximately three-quarters of one per cent. The inference, therefore, is fair that the figures as given above as to saving are reliable. Succeeding months would also have probably shown even more gratifying results, since the figures reported herein cover months rather unfavorable for effecting the maximum effort in reducing fuel consumption. The movement was conducted, however, in an organized way long enough to show the splendid results that come from the coöperation of fuel users and from an organized effort to save fuel.

DISCUSSION ON PULVERIZED COAL AT THE SPRING MEETING

AT the Fuel Session of the Spring Meeting of the Society two papers were presented on the subject of pulverized fuel: namely, Pulverized Coal as a Fuel, by N. C. Harrison, and Pulverized Coal for Stationary Boilers, by Fred'k A. Scheffler and H. G. Barnhurst. Abstracts of these papers were published in the August issue of MECHANICAL ENGINEERING, together with extensive extracts from the large volume of discussion which they elicited. A portion of Mr. J. E. Muhlfeld's discussion, dealing with the performance of pulverized-fuel equipment in locomotive and marine service, which it was not possible to print last month, is given below, followed by the closures of the authors of the papers.

Pulverized Fuel in Locomotive and Marine Service[1]

By J. E. MUHLFELD[2]

FROM a study made of the coal measures in the southern part of Brazil during 1904-06, it was concluded that the native coal was unsuitable for economic use. Later, during 1915-16, at the direction of Dr. Miguel Arrojado Lisboa, then Director of Government-Operated Railways, an investigation was made of the use of pulverized fuel in the United States, with the result that the Central Railway of Brazil decided to install a 15-ton-per-hour capacity fuel-preparing and coaling plant and a stationary boiler equipment at Barra do Pirahy, an enginehouse and shop terminal about 65 miles north of Rio. Plans and specifications were prepared and installation was made of the "Lopulco" system by the International Pulverized Fuel Corporation of New York. Arrangements were also made for the equipping of 250 existing and new locomotives with the same system and by the same company, and since that time twelve ten-wheel-type and two Consolidation-type locomotives have been newly built and so equipped, by the American Locomotive Company, and put into regular use on the Central Railway of Brazil.

The first official run with Brazilian native coal, pulverized, was made on September 9, 1917, with a special train that transported Dr. Wenceslao Braz, President of the Republic of Brazil, and his staff. Ten-wheel-type locomotive No. 282 handled the President's special train from Barra do Pirahy to Cruzeiro, a distance of about 90 miles, and during the greater part of the trip President Braz remained in the locomotive cab and fired the locomotive, on which the steam pressure was fully maintained throughout, without any smoke.

As the result of this performance, President Braz sent a telegram to the Minister of Public Works, as follows:

> From Barra do Pirahy to Vargem Alegre, I traveled on ten-wheel locomotive No. 282, fitted for the use of pulverized fuel, with excellent results. The trip was made with a velocity of 63 kilometers per hour, having a train of 210 units behind it. I take great pleasure to give you this communication which I am certain will be received by all Brazilians interested as solution of one of your most important national problems. Salutation.
>
> WENCESLAO BRAZ.
>
> Barra Mensa, September 9, 1917.

The Central Railway of Brazil locomotives equipped with pulverized-fuel-burning equipment are operating in fast-passenger, mixed-passenger and freight, and freight service, and all are giving excellent results.

In tests recently conducted with Brazilian native coal and lignite the distance traveled during trials was 118 miles and the boiler pressure remained almost constantly at 175 lb., which is working pressure. The results of these tests may be stated as follows:

PERCENTAGE ANALYSES OF FUELS USED

Name	Kind	Moisture	Volatile	Fixed Carbon	Ash	B.t.u. per lb.
Jacuhy	Bituminous	6.10	22.40	45.70	19.80	10,851
Santa Catharina	Bituminous	12.60	36.00	42.10	9.00	10,259
S. Jeronymo	Bituminous	3.00	31.00	39.30	26.70	9,565
Cacapava	Lignite	19.00	36.00	19.20	25.80	5,249

PERFORMANCE DATA

Fuel		B.t.u. per lb.	Quantity burned per trip, net tons	Evaporation, lb. water per lb. of fuel	Ash found in firebox and pan, lb.
Name	Kind				
Jacuhy	Bituminous	10,851	4.19	7.2	176
Santa Catharina	Bituminous	10,259	3.5	7.1	176
S. Jeronymo	Bituminous	9,565	5.419	7.1	198
Cacapava	Lignite	5,249	4.41	7.3	220

The only difficulty met with has been in instructing the enginemen, who were not acquainted with this method of combustion, and for this purpose an illustrated instruction book has been issued to each man.

Only by adopting this pulverized-fuel system has the problem of the utilization of Brazilian fuel, which cannot be burned practically or economically on grates or in retorts, or utilized to good advantage for the production of producer gas, been solved, and the development of the native coal fields of the country is now in process through the establishment of steamship and railway means of transportation from the mines, and in the actual mining developments.

In the United States the development work in connection with the use of pulverized anthracite and bituminous coals and lignite for steam locomotives has been carried out by making application to single locomotives of different types which were distributed on five different railroads of the country in order to determine upon a composite and interchangeable pulverized-fuel feeding, burning and furnace equipment that would be adaptable to any kind or size of steam locomotive, as well as to all possible fuels or combination of fuels locally available, and which at the same time would permit of the quick conversion from pulverized fuel to fuel oil, and vice versa.

When it is taken into consideration how many modifications of firebox, grate, ashpan, brick arch, smokebox draft appliances, exhaust nozzle and stack designs and equipments are required to adapt steam locomotives to the various anthracite and soft bituminous coals and lignites as used for fuel, even on a single railway, it can readily be imagined what the development of a single pulverized-fuel-firing mechanism and furnace arrangement for the entire United States has involved, particularly to make it adaptable to existing as well as new designs of locomotives. For example, the time required for the development and the practical use of fuel oil and of a satisfactory superheater is comparable.

During the past year the financial, labor and material conditions on steam railways, brought about by the war, have prevented any appropriations being made for the equipping of operating terminals and divisions in the United States for the extended use of pulverized fuel, but the result of what has obtained may be summed up in the following data applying to The Delaware and Hudson Company and the Atchison, Topeka & Santa Fe Railway:

On The Delaware and Hudson Company a newly built Consolidation type of freight locomotive, No. 1200, with a tractive power of from 61,400 to 64,000 lb., was equipped for experimental purposes, from March 1916 to August 1917, and operated in road freight service between Carbondale and Plymouth, Pa., and Oneonta, N. Y., on runs of from 37 to 94 miles one way. Pulver-

[1] Supplementing Mr. Muhlfeld's discussion of the Spring Meeting papers on pulverized coal, published in MECHANICAL ENGINEERING for August, p. 658.

[2] Vice-President, Railway and Industrial Engineers, New York. Mem. Am. Soc. M. E.

ized fuel was supplied from The Hudson Coal Company's stationary-boiler experimental pulverizing plant at Olyphant, Pa.

This locomotive was designed for a working steam pressure of 195 lb., but the boiler was designed to carry 215 lb. steam pressure. With 195 lb. working pressure the cylinder horsepower rating is 2368 and the boiler horsepower rating 2540, giving a 107.2 per cent boiler.

Pulverized-fuel tests were made with the following adjustments:

Adjustment	Boiler pressure, lb.	Tractive power, lb.	Factor of adhesion	Results
Original	195	61,400	4.36	O. K.
First change	200	63,000	4.24	O. K.
Second change	205	64,600	4.14	O. K.
Third change	210	66,200	4.03	O. K.

The raw coal which was supplied for these tests analyzed about as follows:

Content	Anthracite slush	Anthracite birdseye	Bituminous slack
Moisture, per cent	14.96	......	7.28
Volatile, dry, per cent	6.95	6.75	22.47
Ash, dry, per cent	23.67	75.23	57.21
Calculated B.t.u. per lb	11,800	12,600	13,700

This raw coal was mixed in the proportion of 60 per cent anthracite and 40 per cent bituminous, which, after drying and pulverizing, produced a fuel of from 15 to 20 per cent volatile content. This was entirely satisfactory for locomotive purposes and yielded an average of one boiler horsepower for each 1.4 sq. ft. of combined firebox and tube heating surface.

Dynamometer-car tests conducted to determine sustained pulling capacity on heavy grades and at starting gave the following results:

Maximum dynamometer drawbar pull, lb.	Speed, miles per hour	Reverse lever cut-off, per cent	Throttle opening, per cent	Boiler pressure, lb.	Grade on line, per cent
64,000	At start	Full	75	200	1.65
59,000	6	66	Full	205	1.65
58,000	8	66	Full	205	0.72
56,000	$10\frac{1}{2}$	66	Full	205	0.72

During these tests a fuel mixture of 60 per cent anthracite birdseye and 40 per cent bituminous slack was used, and the apparent evaporation ranged from 7.3 to 9.3 lb. of water per lb. of coal consumed. The coal fired per 1000 ton-miles averaged 202 lb.

In heavy-tonnage-service runs—over ruling grades of from 0.72 to 1.65 per cent—for a distance of 37 miles the following data show typical performance:

Item	Trip No. 1	Trip No. 2
Miles run	37	37
Speed, average, miles per hour	14.5	13.1
Ton-miles, actual	83.147	85.758
Ton-miles, adjusted	88.553	90.113
Coal consumed per 1000 ton-miles	186	202
Steam pressure, average, lb	199	200

When in heavy-mine-run service between Carbondale and Olyphant, Pa., for the three months' period, March 13 to June 12, 1917, the performance of the No. 1200 was as follows:

Period From	Period To	Days in road service	Hours in road service
1917	1917		
March 13	April 12	28	301 hr. 3 min.
April 13	May 12	27	301 hr. 30 min.
May 13	June 12	25	273 hr. 10 min.
Total...	....	80	875 hr. 43 min.

After the day's work, upon arrival at the Carbondale engine terminal, the locomotive would be run directly into the house, no fire, track or ashpit delays or work being required.

On the Atchison, Topeka & Santa Fe Railway an existing Mikado type of freight locomotive, No. 3111, with a tractive power of 59,600 lb., was equipped for experimental purposes—from May 1917 to July 1918, and operated in road freight service between Fort Madison, Iowa, and Marceline, Mo., on runs of 112.7 miles one way. Pulverized fuel was supplied from the company's experimental pulverizing plants at these points.

Dynamometer-car tests were run with the following average results, using Frontenac, Kan., run-of-mine bituminous coal, averaging in analysis when pulverized as follows:

Moisture, per cent	1.05
Volatile, per cent	32.67
Fixed carbon, per cent	51.57
Ash, per cent	14.71
Sulphur, per cent	3.95
B.t.u. per lb.	12,022
Per cent through 100-mesh	97.8
Per cent through 200-mesh	82.6

The general performance of the locomotive equipped with the Lopulco pulverized-fuel system was as follows:

Date of runs	Mar. 4 to Mar. 22, 1918
Total trips run (112.7 miles each)	14
Total miles run	1578
Average running time	5 hr. 6 min.
Average speed, miles per hour	22.3
Average train tonnage, net tons	2273
Average gross 1,000 ton-miles	256.5
Average coal per gross 1,000 ton-miles, lb	82.4
Average water per gross 1,000 ton-miles, lb	566
Average boiler pressure, indicated, lb	188
Average feedwater temperature, deg. fahr	48
Average flue-gas temperature, deg. fahr	553
Average smokebox draft, inches of water	11.3
Average firebox draft, inches of water	1.3
Average quality of steam, per cent dry	96.0
Average superheat in steam, deg. fahr	233
Average lb. of coal per hour of running time, per equivalent sq. ft. of grate area	71.3
Average lb. of coal per hour of running time, per sq. ft. of boiler heating surface	1.07
FUEL PERFORMANCE	
Equivalent evaporation, lb. of water from and at 212 deg. fahr. per lb. of coal for boiler and superheater	9.22
Per boiler horsepower for boiler and superheater	11.15
Combined efficiency for boiler and superheater, per cent	74.5
Thermal efficiency for locomotive, per cent	4.19

An actual evaporation (not corrected for the quality of steam) showed at the rate of 8.46 lb. per sq. ft. of boiler heating surface.

The combined boiler and superheater efficiency showed a gain of 23.2 per cent for pulverized fuel as compared with hand-firing.

Based on the hand-firing performance, the use of pulverized fuel showed a saving of 22.5 per cent in fuel. The combustion was practically smokeless and the pulverized-fuel operating mechanism gave no trouble.

Fig. 1 shows a typical application of a pulverized-fuel-burning furnace as adapted to a modern steam-locomotive type of boiler for the use of any solid fuel having 15 per cent or higher volatile, or for fuel oil, regardless as to the other chemical characteristics.

Marine Service

During September 1918 quite a number of tests were made on the USS *Gem* (SP-41) on Long Island Sound to determine what results could be obtained from the use of Navy Department specification coal in pulverized form as compared with oil and other fuels.

One of the two Normand type of water-tube boilers was equipped with two pulverized-fuel feeders and burners, the furnace being fitted up with firebrick in a manner that would enable the use of either pulverized coal or fuel oil, or a combination of both. On account of the boiler not being equipped with induced draft the pulverized-fuel induced-air burners were connected to the regular air-blast system instead of being open to the atmosphere.

The characteristics of the coal used, after pulverization, were as follows:

Moisture, per cent	1.02
Volatile, per cent	18.70
Fixed carbon, per cent	75.10
Ash, per cent	5.18
Sulphur, per cent	0.65
B.t.u. per lb	14,975
Fineness:	
Percentage through a 200-mesh screen	83.6
Percentage through a 100-mesh screen	92.0

On September 18, 1918, a four-hour run was made, from 8.30 a.m. to 12.30 p.m., during the last two hours of which the most economical speed for the ship, i.e., 16 knots per hour, obtained, and which enabled the engines to take the steam as fast as generated. This speed was maintained for the two-hour period, and then, as during the entire four-hour test run, the furnace operation was good—there was no heat effect on the refractory—and there was either no smoke, or it was very light; there was no accumulation of slag or ash on the boiler tubes or settings, and had the boiler been equipped with induced draft the efficiency results would have been better and the light smoke that was produced would have been entirely eliminated.

The log of the test for the last two hours of this four-hour continuous run was as follows:

TEST No. 23, SEPTEMBER 18, 1918

Time fired up	8.30 a.m.
Time of test	10.30 a.m. to 12.30 p.m.
Duration of test, hours	2
Average speed, knots	16 approx.
Average boiler pressure, lb	210
Average superheat, deg. fahr	67.5 (max. 86)
Average flue-gas temperature, deg. fahr	541 (max. 570, min. 500)
Average indicated horsepower	751
Average revolutions per minute	261.5
Total pulverized fuel fired, lb	3,235
Coal per i.hp.-hr., lb	2.15
Total water evaporated from and at 212 deg. (on basis of 25 lb. per i.hp.-hr.), lb	37,550
Water evaporated per lb. of coal from and at 212 deg., lb	11.6
Boiler efficiency, per cent	75 approx.
CO_2, per cent	Avg. 13.5, max. 14, min. 13
Coal	Pocahontas Bituminous
Lopulco system equipment operation	Good
Lopulco system furnace operation	Good
Smoke	Light
Brickwork heat effect	None

This same boiler when using fuel oil of about 18,500 B.t.u. and when operating at a speed of 14 knots, develops an indicated horsepower-hour on 1.68 lb. of such fuel. Therefore, with coal of 14,975 B.t.u., in order to give equivalent results it should use 2.08 lb. per i.hp-hr.; whereas the performance at 16 knots shows 2.15 lb. per i.hp-hr.

A comparison of superheat as obtained with straight pulverized fuel and with fuel oil, respectively, on various test trips, is given in the following table:

Pulverized Fuel			Fuel Oil		
Trip No.	Average knots	Average superheat deg. fahr.	Trip No.	Average knots	Average superheat, deg. fahr.
22	10	43	14	10	45
17	12	73	16	12	70
23	16	66	24	14	58

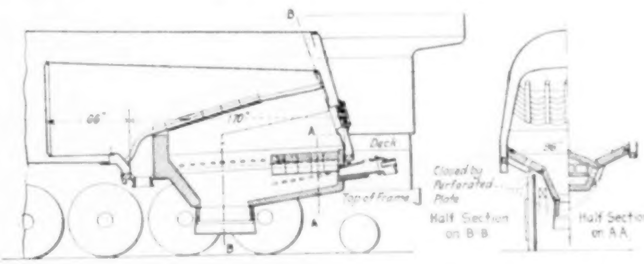

Fig. 1 Typical Application of a Pulverized - Fuel - Burning Furnace to a Steam-Locomotive Boiler

Closure of Messrs. Scheffler and Barnhurst

Mr. Marsh prefaces his remarks with a reference to the desirability of utilizing the by-products from coal. It appears to the authors that this is not pertinent to the discussion and that it will not require consideration until it becomes common practice to remove the by-products from coal before firing on hand grates or stokers. The inference is that pulverized coal cannot be burned after removing the volatile constituents, a supposition which is not borne out by the facts. His statements that pulverized coal is restricted to a field comprising forms that cannot be burned on stokers is an admission that pulverized fuels increase the latitude of combustibility and is not supported by evidence.

In reply to Mr. Marsh's objections to the tests submitted, it should be noted that with pulverized fuels uniformity of operation is obtained and maintained in a short time after firing the furnaces, and the variation in the figures need not be expected by prolonging the tests. In particular in the test made May 18, 1919, on one of the 600-hp. B. & W. boilers at the plant of the Puget Sound Traction, Light and Power Co. at Seattle, during which both the coal and water were weighed, the duration of the test being $13\frac{3}{4}$ hours, the efficiency obtained was 78.99 per cent with coal containing 10,106 B.t.u. per lb. as fired.

In regard to the figures assumed for stoker efficiency, it is submitted that the best information we have been able to obtain shows that an average efficiency of 65 per cent may be expected in modern power houses. Where power is not produced for sale this figure appears to be too high. Mr. Marsh does not substantiate his objections to these figures.

In regard to reliability, it is customary to duplicate a sufficient proportion of the pulverizing equipment to obviate irregular operation in pulverizing plants. This is taken care of in the figures on investment charges given in the paper and makes unnecessary Mr. Marsh's assumption that the investment charges quoted are too low.

In reply to Mr. Marsh's question as to the latitude of pulverized-coal furnaces, it should be stated that a furnace built for high-volatile bituminous coal will not handle anthracite or coke breeze. Where a considerable variation in the grade of available fuels is to be expected, however, the furnace may be designed to burn anthracite or coke breeze and will then be able to handle any grade of bituminous fuel with slight changes in the arrangement of the burners. It is a matter of surprise to the authors that the tests mentioned by Mr. Marsh show that the fire was unresponsive with low-volatile coals, since it has been their experience that the flexibility of all grades of fuels when pulverized exceeds that obtained when burned in lump form. The burner for pulverized fuel is very simple and has a wide range of adjustments, easily meeting any requirements made upon it by a change in the fuel.

In regard to adaptability, the effect of ash in coal is to carry away a small amount of heat as the percentage increases. The excess air required to burn fuels of the highest ash percentage is, however, negligible. It may be stated in regard to the varied efficiencies shown in the tests that pulverized-fuel furnaces require proper design as well as any other type, and that tests in many instances were a part of the experimental development and variations were to be expected.

In regard to the burning of high-ash coal on chain grates, it should be stated that the 28.4 per cent ash fuel mentioned by the authors was tried out on chain grates and was a failure. The stokers were taken out after they had been proved incapable and return was made to hand firing.

In regard to flexibility it is readily admitted that pulverized fuel requires large furnace volumes to burn successfully. It should be noted, however, that other types of fuels, including oil, are burned more efficiently with large furnace volumes, and that the best new stoker installations have furnace volumes as large as required for pulverized coal. The amount of heat that may be developed in a furnace with pulverized fuel is restricted only by the resisting powers of the refractories up to this maximum. The flexibility of control far exceeds that obtained with any other method of burning solid fuels. The upper limit is merely a matter of design and rating.

Under the head of furnace design Mr. Marsh again protests against the inclusion of tests of four or five hours' duration. This has been answered above.

Mr. Marsh objects to the figures used for moisture percentage in coals. It may be stated that our tables were based on a general average moisture content for the entire country. Further, the figures given for pulverizing cost are the result of present information and the best obtainable. They will not vary greatly except under unusual conditions.

We must take exception to Mr. Marsh's statement that three-quarters of the ash goes out of the chimney. Generally speaking, 20 to 25 per cent will remain in the combustion chamber and 30 to 40 per cent in the second and third pass, and the balance in the flues and out of the stacks. Very little settling takes place after the gases leave the boiler. With coal containing 10 to 15 per cent ash the stack discharge is not objectionable, even in cities. With higher ash content it might be necessary to provide dust collectors in the flues in city power plants.

In answer to Mr. Marsh's question, pulverized coal is stored in closed tanks, absorbs moisture very slowly, and under the methods of installation in use does not stay in storage for any considerable period.

Mr. Marsh criticizes the authors' claims for range of fuels, and follows by asking of what value the capacity to handle both anthracite and lignite may be. It is self-evident that with such a range as this many of the intermediate fuels may be burned. His statement that the cost of drying and pulverizing fuel in installations of from 500 to 600 tons daily capacity is over $1 per ton is at variance with figures obtained from hundreds of plants and upon which our estimates are based.

Mr. Diman is correct in stating that there is a limit to the quality of low-grade fuels that can be used in pulverized form. There is no doubt that if the coal is too low in combustible the cost of grinding would overcome any advantage obtained in economy of burning these coals in pulverized form. Success in burning anthracite depends upon the form of the furnace. As the coal lacks volatile, increased temperature must be generated near the burner, and this is accomplished by the use of some of the products of combustion from the furnace itself. This means designing the furnace so that there is a returning flame to ignite the incoming fuel. With this arrangement very satisfactory operating efficiencies are being obtained, and there is no trouble in starting a furnace so designed in but a little more time than that required with pulverized bituminous coal.

In Mr. Peabody's discussion of Mr. Harrison's paper he states that oil is undoubtedly superior to all other fuels for boiler purposes, and that the furnace volume required for oil fuel is only about one-quarter of the furnace volume specified in the paper for pulverized coal. Mr. Harrison recommends a larger combustion chamber than we know is actually required, but we have found that where oil is fired in pulverized-coal furnaces much better efficiency is obtained than is obtained in furnaces designed for oil alone. Larger combustion chambers are constantly being installed under all boilers for the purpose of obtaining better combustion conditions. This is due to the fact that the best mixtures of the air and carbon or coal cannot be made with the present method of oil or lump-coal firing.

The slight extra cost of the larger furnaces required is more than overcome by the increase in efficiency obtained over other methods of firing. It has been mentioned previously that combustion chambers recommended for pulverized coal are no larger than those now being used in a great many stoker installations.

Mr. Hirshfeld has probably not examined very many pulverized-coal-fired furnaces, or he would have found that there is hardly any trace of combustible in the ash in the furnace. We do not agree with his statement that a more uniform flame and temperature can be obtained with stoker practice due to the smooth bed of incandescent fuel. A fuel bed is a very uncertain quantity in the average furnace. It cannot remain of constant thickness or of constant quality. The conditions of the fuel bed are beyond control, and the coal must frequently be redistributed by the fireman. Certain types of stokers must be watched constantly and the holes in the fire bed kept covered with fuel.

In reply to Mr. Hibbard, the authors would state that drying of the coal is necessary for the purpose of properly pulverizing it. The injection of water or steam into the firebox is a dead loss, and is resorted to only as a means to overcome defects in the method of burning fuels. There is no occasion for this with pulverized fuel.

The experiments mentioned by Professor Young have no connection with the subject of pulverized-coal burning, because the quality of the material with which he has been experimenting is thousands of times coarser than the standard pulverized coal as now being used for commercial purposes.

Mr. Frey takes up the cost of pulverizing coal, basing his statements on data obtained from a first-class power house. We are doubtful, however, even in this power house, as to whether the evaporation from the coal that he is using would average 6 lb. of water on the average over a year's operation, and if the evaporation was increased only 50 per cent, certainly the increased efficiency obtained from the fuel would more than counterbalance the extra cost due to pulverizing unless the coal is obtained for practically nothing.

It is evident that the lower the price of the coal the larger must be the plant and the lower the cost of preparation to show economies warranting its application, but the cost of coal is going up steadily on account of the increased demands for fuel for manufacturing purposes.

Mr. Wotherspoon's remarks had no bearing on the subject of the application of pulverized coal to boiler-firing work, with the exception of his reference to the Bettington boiler experiments, which were made a number of years ago, and which were an entire failure so far as practical operation was concerned.

Mr. Snyder's remarks are noted with interest. The question of the adoption of pulverized coal to power houses is only warranted where the cost of operation would show a fair interest on the investment. We admit that stoker plants are operated with high efficiency under careful management, but we believe that pulverized coal will show increased efficiency and lower cost of operation than the average stoker installation, particularly in plants using a large enough quantity of coal to permit obtaining a low cost of preparation.

Mr. Stevens offers information, which he obtained from a prominent engineer, to the effect that $2\frac{1}{4}$ per cent of unconsumed carbon passes out of the stacks with stokers. This is a condition that is not possible with pulverized coal in furnaces properly proportioned and operated correctly.

Mr. Riley's remarks are particularly gratifying in that he fully realizes that the question of the adoption of pulverized coal is a matter of dollars and cents, and that its application in any installation is a question of which system will give the best returns for the money invested.

Mr. Trump spoke of experiments made in past years, and the writers particularly wish to point out that the furnace was too small for the boiler which he used, or else the quantity of coal fired to the furnace was beyond its capacity for satisfactory service. Furthermore, in the earlier days the fineness of pulverization was so much coarser than that now used in standard practice that there is no comparison, and the results obtained could not possibly have been satisfactory enough for commercial purposes.

Mr. Cary is correct in his statement that the idea of the use of pulverized coal has been in the minds of engineers for many years. Many experiments and thousands of dollars have been spent in an endeavor to accomplish this purpose. It has, however, been an evolution, and the earlier disastrous results were strictly due to the fact that sufficient knowledge of the subject was not at hand. The engineers did not realize that it was not the pulverizing of the coal that caused the trouble, but the fact that they tried to burn this kind of fuel, which is nearly in the form of a gas, in a furnace designed for lump fuels.

We would like to mention in regard to Mr. Cary's statements that today the fineness of pulverized coal is such that it practically all passes through the 50-mesh sieve, which means that the largest particles are less than 0.01 in. in diameter. The velocities are slow enough to insure the complete combustion of the particles of this size, hence it is not necessary to go to the extra cost of pulverizing to any higher degree of fineness than is now practically the standard, which equals 95 per cent through a 100-mesh sieve and 85 per cent through a 200-mesh sieve, all passing through the 50-mesh.

In closing, the authors wish to express their appreciation of the attention and interest accorded them, as evidenced by the discussion. It is not their wish to present the pulverizing of fuels as a modern panacea, but merely to lay before the Society a statement of its possibilities and to remove some of the fallacies in regard to it which have had more or less general circulation.

Mr. Harrison's Closure

I note that Mr. Marsh states in his discussion that I have used pre-war prices for the cost of pulverizing. He has cited the cost used in Table 1, whereas he should have used the cost shown in Table 3, or rates of 40 cents for millers and 35 cents for laborers and $5 a ton for coal. These are not pre-war prices, but are the present-day prices as paid by the Atlantic Steel Company.

Mr. Marsh also speaks about pulverized coal picking up moisture when stored. I thoroughly agree with him on this, but every one who uses pulverized coal has found by experience that this fuel must not be stored. It must be kept moving at all times in the bins, consequently there is very little moisture picked up by the pulverized coal from the air.

I note in several discussions that considerable comment has been made regarding the height of stacks necessary for the use of pulverized coal on boilers, as spoken of in my paper. During February I visited one plant installed in Kansas, and saw boilers working there very satisfactorily with a stack of about 35 ft. in height.

Most of the comment has been that we should have a draft of 0.10 in. in the combustion chamber and a draft of from 0.20 in. to 0.60 in. at the damper. This has not been my experience for the best burning of pulverized coal under boilers. I believe that we should have practically a balanced draft in the combustion chamber and first passage through the tubes, and from 0.10 in. to 0.20 in. at the damper. These figures are based on 150 per cent of rated capacity. Of course, if the boiler is intended to be worked at a larger rating than this, it would be necessary to have larger stacks.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of MECHANICAL ENGINEERING by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

Recognition of Engineering Service by the Government

To the Editor:

Those who are fortunate enough to live or work near the trunk-line railroads have grown accustomed to the daily passage of troop trains. For six months these have been homeward bound, to the delight and relief of all. "We are gladder to see them going that way than the other," has been the homely expression of the multitudes who have waved at the boys as they swept by.

And the most highly prized of the possessions of the returned soldier is his discharge. For many years this will be exhibited with pride. Money could not buy it. Long after his friends have forgotten his record of war service and the memory of those days has become dimmed, that bit of paper stands as evidence of the deeds which each man performed for his Government. That discharge is the only concrete form in which his part in the great struggle is preserved—a form that is universally accepted—one that may be of benefit to the holder in many ways in the years to come. No one but admits that this is little enough from his country to compensate for the sacrifice and no one but rejoices in his possession therof.

Turning now to the vast army behind the army, should not service in its forces be recognized by some tangible mark or document? No profession contributed more than that represented by our Society, and yet it seems that after the hour of need has passed its work will go without commemoration. Just as the engineer has not been given the recognition which was his due from the public, so is the engineer being officially slighted, though probably unintentionally.

Engineering services differ from all other purchasable commodities in that they cannot be manufactured or forced—no system of intensive production can glut the market with them; like the mighty oak, they are a product of slow growth. It was the rounding up of the country's resources of engineering that was largely responsible for the "year earlier than expected" result; and the world marvelled at the speed and volume with which the supplies, from bullets to ships, were turned out to back up the boys at the front.

There should be (at least upon request) available some form of recognition for those engineers who gave so freely out of their experience and learning. Such form should hold equal value with other documents in the business world, in politics, as civil-service rating, and in the eyes of the public at large.

Donald A. Hampson.

Middletown, N. Y.

Foreign Coals and Stoker Installations

To the Editor:

American engineers are at an increasing rate being called upon to design and build power plants in many other countries. Successful engineering will establish American engineering practice and will have a similar reflection upon the American equipment. It is therefore important that engineering be based on accurate knowledge instead of any uncertainties as are likely to exist, due to the remoteness of the market.

In power-plant design the one big variable in any location is the fuel. This is a major problem, because no stoker or method of firing so far developed is suitable for all fuels, necessitating a thorough knowledge of the coal and its characteristics for a proper selection of stokers and furnace equipment.

Some fuels are definitely known to be unsuitable for certain stoker types and yet not infrequently installations are made under these conditions, due usually to a lack of actual knowledge of the fuels available to the market.

While we have hundreds of books discussing the chemical analyses and geological formation of our various coals, there is a lamentable lack of knowledge of how to burn these coals as commercially received, considering combustion rates, clinker, attendant labor and other items. No engineer can predict successful installations without such knowledge of the coals of all districts into which he markets his product.

If it is necessary to know the fuel characteristics of American coals to produce successful installations, it is certainly much more imperative to know those of the foreign coals, if failures are to be eliminated and successes assured.

Those of us who have been fortunate enough to work on combustion problems with the fuels of practically every country have accumulated some data relative to the composition and characteristics of foreign fuels, a brief general outline of which is presented. Any discussion must of necessity be general, as it is impossible to become specific regarding fuels without taking them up district by district and seam by seam.

North America. The United States produces the maximum coal tonnage of the world, most of it being bituminous.

Canada has a good production, mostly bituminous and lignite, including coals of wide variation in characteristics as to moisture content, clinkering and coking.

Newfoundland. Some bituminous coals are found, but not extensively developed.

Mexico. The coals of Mexico are found along the northern border, being probably an extension of our own Rocky Mountain fields. Some fairly good bituminous and semi-bituminous coals are found.

Central America. A small amount of coal exists in this country.

South America. Colombia has a small production of bituminous coal, as has Venezuela, Argentine and Chile. Peru has some anthracite deposits in addition to the bituminous coal.

The grade of coal found in South America is not high and it is burned with difficulty. Much Welsh and American coal is now imported, as the native coals offer little competition even with Welsh and American coals selling at thirty to forty dollars per ton in Buenos Aires.

Africa. Bituminous coal is found in the Belgian Congo, Southern Nigeria, Rhodesia and the Union of South Africa. The latter country also has a considerable deposit of anthracite.

While the production of coal in Africa is not large, some very good fuel is mined, and some very creditable stoker installations have been made.

Asia. China and Japan produce coal in considerable quantities and there are many large power stations stoker-fired. China has deposits of anthracite equal to twenty times those of the United States, so it is natural that a good portion of the steam generated in China will be from this fuel.

One sometimes hears the statement that Japanese, Chinese or other coals are suitable for a particular type of stoker. The statement is just as loose and unscientific as to state that the coals of America are suitable for any specific stoker. These countries have coal deposits of every class that we have in the United States and a knowledge of the specific fuel is necessary before it can be positively said that a certain stoker is suitable.

Korea, Manchuria, Siberia, Indo-China, India and Persia have considerable coal, but not extensively produced. In the latter three countries anthracite predominates.

Europe. Great Britain and Ireland stand second in the world production of coal and first in quality. The Welsh coals are the finest and most widely distributed fuels of any in the world. The British merchant marine bring cargoes of food stuffs or merchandise to Great Britain and make the return trips with a cargo of Welsh coal. This is one of the difficulties with which we are confronted in attempting to secure a wider export market for American coals.

Our coals nearest approaching Welsh coal are Pocohontas and New River, but most Welsh coals are superior to all but the choicest samples of our coals. Fifteen thousand to fifteen thousand five hundred B.t.u. per pound is characteristic.

Spain and Portugal do not produce coal extensively. France is a large producer of all grades of coal and should offer a good field for stoker installations.

Italy, Greece, Bulgaria, Denmark, Netherlands, Bosnia, Servia, Roumania, Sweden and Spitzbergen are all small producers of coal—mostly bituminous and sub-bituminous.

Belgium, Germany, Austria and Russia are large producers, the latter country having extensive anthracite deposits (almost double those of the United States).

Oceania. Australia has extensive coal deposits, a large proportion of which are of a very fine quality; the production is fairly large.

New Zealand, British Borneo, Dutch East India and the Philippines all have a small production of various coals of a bituminous, subbituminous and lignite nature.

In practically all of these countries there are some stokers. Some of the installations have been characterized by a wrong selection of stoker types, due to reasons discussed in the foregoing paragraphs.

Chain grates, due to their simplicity of operation and adaptability to burn all grades of bituminous, sub-bituminous and lignite fuel, have produced noteworthy results in most foreign countries and over a wide range of operating conditions.

It is very much to be hoped that in combustion engineering as in other lines of endeavor, American engineers will base their conclusions on accurate knowledge of the fuel and its characteristics and will conscientiously refuse to install stokers for conditions which are for any reasons unsuitable. On any other basis the industry as a whole suffers and our engineering is discredited in foreign markets, to the detriment of future export trade.

T. A. Marsh.

Chicago, Ill.

Discussion of Society Policy Urged

Mr. Calvin W. Rice, *Secretary:*

On page 688 of the August number of Mechanical Engineering there is a letter on Contributions on Society Policy by Mr. Morris Llewellyn Cooke addressed to the Secretary and also a reply by the Secretary.

I wish to urge on the Publication Committee that it find room in the Journal for suggestions on Society affairs and other contributions in this Correspondence section. Particularly contributions on Society affairs are desirable as distinguished from technical matters. Theoretically the Journal is very ready to publish such contributions, but practically its attitude gives the impression that it rather discourages them. Mr. Rice mentions a suggestion by Mr. Crawford and which is: "My reply to that was in effect that we were already doing what he proposed, but nevertheless, if he would condense his letter, we would be glad to publish it. He never came back."

Would it not have been decidedly better to have published Mr. Crawford's communication, if necessary, by condensing it rather than let the impression go abroad that possibly such a contribution was not welcome? As suggestions are undoubtedly wanted and are undoubtedly also welcome, even though that may not seem to be the case, it would be well to give possibly unnecessary space, as that would prove the welcome to be an actual fact and would probably gradually draw out more comment, some of which, no doubt, would be useful and constructive even though a great deal of it might simply be the airing of personal opinions.

Every member who chooses to so air his opinions is entitled to that privilege and it should be unhesitatingly extended to him even though it might, to some extent, crowd out some other matter.

I believe that if a properly worded questionnaire on this point were to be sent out, it would show very considerable interest

among the membership along this line. Everything will, of course, depend upon the wording of the questionnaire, as nothing is easier than to draw out any desired information by skilful phrasing of the questions asked.

Henry Hess.

Philadelphia, Pa.

[The Secretary has frequently told Mr. Hess that he is one of the most useful members of the Society and the Secretary takes satisfaction in again acknowledging the excellence of Mr. Hess's suggestion, and the following is the letter from Lt.-Col. Crawford, published in full.—The Secretary.]

My dear Mr. Rice:

Some little time ago, there came to me a circular letter over the signature of Mr. Walter B. Snow, promoting the circulation of the journal Mechanical Engineering by asking members of the Society to tell young acquaintances something of its undoubted merits.

About the same time there came from a friend a personal letter which advised me that at the present time there are more than twenty local unions of draftsmen and engineers in subordinate capacities already in existence around over the country, claiming a membership of three thousand, who are affiliated with the American Federation of Labor. An unverified rumor of a Civil Engineers' Union somewhere in Connecticut has drifted in.

Every member of our Society worthy of the name is and should be glad to help it or its Journal, but before we make an effort to spread the Journal's circulation widely, might we not be advised in a little introspection for the sake of some of these prospective members whose state of mind is indicated by the facts above mentioned, as well as for ourselves?

In a letter "to the editor" in the February issue, it is suggested that the Society "encourage the publication of letters . . . about the life of the Society in each issue of Mechanical Engineering." So far as I know, there has been no decision upon this, and before it is decided either to do this or not to do it, the implication should be clearly recognized.

Without perhaps intending it, the policy of the A. S. M. E. always has appeared to be to deprecate the open discussion of its affairs—especially after such affairs had reached the controversial stage. This is one well-recognized method of conducting any enterprise and there is much that can be said in favor of it. Most of us practice it as a matter of course in our private affairs. The opposite method and the one evidently advocated by your correspondent is "to take the lid off" and permit members to register complaints freely either by voice or pen whenever they may feel the spirit's urge. The point I wish to emphasize right here is that between these two policies there is no middle course possible.

If it is decided to encourage the fullest possible discussion of the Society's affairs in the Journal and at its meetings, there is implied a willingness to publish any and every criticism that may be received. It would be obviously unfair to the membership to adopt the policy of an open forum and still retain the censor. Since the subscription lists are open to all who can pay the fee, it might not be out of place or even unwise to open the columns of criticism of our Society to any one who can write and has something to say.

Since this letter is written as a suggestion, why is it not a timely one? Why cannot such communications be encouraged by an unequivocal and emphatic statement that all criticisms received will be published? Surely, letters written by members in good standing are entitled to such treatment. There is another phase to this procedure, as it is the testimony of every one of whom I know who has had the experience of adopting such a course that during a short period there may be too many carping and fault-finding letters, but these soon exhaust themselves and the way is open and well paved for the era of constructive suggestions coming from the membership. It is these that we need and for which we can afford to pay the price in introspective house-cleaning. Consider what our Society might be if we could induce each of its ten thousand members once in a while to express his views on the purposes of the Society and the methods of their realization.

Can we not wisely decide to encourage in every way at our disposal the freest possible expression of public opinion as to Society activities? If in rare instances there is no foundation for a criticism, it will fail from its own ineptitude and no harm will have been done. But when there is a cause for critical or fault-finding comment, we all want to know about it and see that the fault is corrected while at the same time its cause is removed.

The writer is neither a reformer nor a crusader, as you know, but he does feel that if we were doing all that our pooled intelligence, facilities and experience could make possible for the engineering sciences and the profession at large, crowds of our younger prospective members would not be forming labor unions and there would be no need for members of the Society to solicit subscriptions for its Journal.

With kindest personal regards and my best wishes at all times,

Very sincerely yours,

C. H. Crawford.

Rio de Janeiro, Brazil,
March 13, 1919.

Strengthening of the Patent Office

The Patents Committee of Engineering Council has collaborated with the similar committee of the National Research Council in developing a scheme for the improvement of the method of dealing with patents in this country. The staff of the Patent Office is itself actively engaged in this effort.

Out of the report prepared by the National Research Council, and approved and adopted by Engineering Council as the report also of its Patents Committee, remedial legislation has taken form, and the following bills have been introduced in the House of Representatives:

> House Bill 5011, being a bill "To establish a Patent and Trade-Mark Office independent of any other department and to provide for compensation and infringement of patents in the form of general damages, and for other purposes."
>
> House Bill 5012, being a bill "To establish a United States Court of Patent Appeals, and for other purposes."
>
> House Bill 7010, being a bill "To increase the force and salaries in the Patent Office."

Mr. Edwin J. Prindle, Mem.Am.Soc.M.E., Secretary of the Patents Committee of the National Research Council, has recommended the publication of this notice in Mechanical Engineering to prompt mechanical engineers to write to the chairmen or members of the Patents Committees of the Senate and of the House of Representatives urging passage of the bills approved by the National Research Council. The personnel of these committees is as follows:

Committee of Patents of the Senate

George W. Norris, *Chairman*	Nebraska
Frank B. Brandegee	Connecticut
Philander C. Knox	Pennsylvania
Frank B. Kellogg	Minnesota
William F. Kirby	Arkansas
Ellison D. Smith	South Carolina
Thomas P. Gore	Oklahoma

Committee on Patents of the House of Representatives

John I. Nolan, *Chairman*	California
Florian Lampert	Wisconsin
Loren E. Wheeler	Illinois
Albert H. Vestal	Indiana
William J. Burke	Pennsylvania
Albert W. Jefferies	Nebraska
John C. MacCrate	New York
Guy E. Campbell	Pennsylvania
John B. Johnston	New York
John J. Babka	Ohio
E. L. Davis	Tennessee
John McDuffie	Alabama

The report of the Patents Committee of the National Research Council was published in the February issue of Mechanical Engineering, page 147.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A. S. M. E.

The Bureau of Research of the American Society of Heating and Ventilating Engineers

THE American Society of Heating and Ventilating Engineers has recently issued a Bulletin on their Research Bureau under the Directorship of Prof. John R. Allen, who has resigned from the Deanship of the College of Engineering and Architecture of the University of Minnesota to take up these new duties.

The following regulations have been adopted by the Society for the control of the Bureau of Research:

First: That there be a standing committee known as the Research Committee and consisting of 15 members, each serving for three years, five retiring each year.

Second: *a* That the Council shall nominate, previous to October 1st of each year, five members to fill the vacancies of those retiring at the next annual meeting.

b That the nominations made by the Council shall be published in the October issue of the Society's Journal.

c That prior to December first of any year, any ten members over their own signatures, may nominate one or more additional members of the Research Committee, and such additional nominations shall be placed on the ballot opposite the nominations made by the Council.

d The election shall otherwise conform to the regulations provided for the election of officers.

e Vacancies may be filled by the Council, such persons chosen by the Council to serve until a successor is elected at the next Annual Meeting.

Third: The Research Committee shall be divided into various Sub-Committees, as may be found desirable to carry on the activities of the Bureau of Research.

Fourth: The activities of the Research Committee shall include:

a Investigations of the need for research in any particular subject, and if such need is sufficient to warrant consideration from the standpoint of pure engineering, to appoint a sub-committee to

1 Collect all existing data and records
2 Carefully examine the records and report on the actual need for further work
3 Report on all available laboratories of colleges and other institutions, which might be utilized
4 Make definite suggestions for the line of procedure to be followed in research work and to confer with and advise the Director of Research upon this particular subject.

b Where research work is found necessary and the course of procedure is obvious, to negotiate with laboratories of colleges or other organizations, as offered, or order work handled by the Director of the Bureau. No work should be assigned to the Bureau which can be handled equally well elsewhere.

c If a sufficient amount of existing data appears to be available for analysis by Committee, to present a synopsis of such data to the next regular meeting of the Society for discussion and approval.

d To report all conclusive data, whether originating through the Research Bureau or Committee, or elsewhere, to the next regular meeting of the Society for discussion and approval.

e To report on questions of finance, ethics and commercialism.

Fifth: *a* One of the sub-committees of the Research Committee shall be known as the Research Executive Committee, and shall be composed of four members, one of which shall be the Chairman of the Research Committee. The Research Executive Committee shall conduct all the business of the Research Committee. It shall make the necessary contracts for rental and purchasing of equipment or material. It shall select and employ the director and such assistants of the Bureau of Research as may be required. It shall determine all salaries and approve all expenses incurred. It shall determine the rotation in which the subjects shall be investigated by the Bureau of Research.

b The Executive Committee shall not make contracts in excess of the income to the Research Bureau without the approval of the Research Committee and the Council.

Sixth: The Chairman of the Research Committee shall be ex-officio member of all sub-committees.

Seventh: *a* All acts or reports of sub-committees shall be subject to the approval of the Research Committee.

b All acts of the Research Committee shall be subject to the approval of the Council.

Eighth: *a* Each Chapter of the Society shall appoint a Research Soliciting Committee, which once per year shall conduct a campaign in its locality to procure funds for the maintenance of the Bureau of Research. Committees may be appointed by the Research Executive Committee in other localities not covered by the Chapters to conduct such campaigns in such territories.

b All moneys received for the Bureau of Research shall be kept by the Treasurer of the Society and used only for the purpose specified.

c The Research Bureau shall operate upon the budget plan. All payments from the Research Bureau fund are to be made by the Treasurer in accordance with the existing present plan for payment of the Society's bills, as authorized by the Council meeting of August 16, 1917, excepting that certification of the voucher by the Secretary of the Society is to be replaced by certification by the Chairman of the Research Committee or the Research Executive Committee. All special items are to be approved by the Research Executive Committee instead of the Finance Committee of the Society.

Ninth: Reports of activities of the Bureau of Research shall be sent to all members of the Society and to all subscribers to the Research Bureau Fund.

The Research Committee at its first meeting on March 10, 1919, unanimously passed the following resolution:

Moved, That in order that the activities of the Research Bureau shall be above reproach, it is the sense of the Committee that no tests, experiments, or research shall be conducted for compensation.

At present the Society has had total subscriptions amounting to $18,000 per year. The Bureau of Mines will donate the services of investigators, office space, janitor service, physical and chemical laboratories, use of special laboratory in connection with power house, service in the form of steam at high and low pressure, direct and alternating current, hot and cold water, gas and the use of such apparatus as may be available. It is estimated that this will amount to a money value of $20,000 per year.

The special activities which will be undertaken by the Bureau of Research are the investigation of the various systems of heating and the accessories on the market which are claimed to increase the efficiency or the comfort of present installations. Another problem is the establishment of air standards, based on moisture content in place of temperature.

Past-President Still expresses his ideas as to the function of the Bureau of Research as follows:

One of the first things on which the work will be centered will be an effort to determine what physical condition of the atmosphere must be produced in order to maintain the same perfectly healthful effects as are obtained in pure, clean, fresh outdoor air. This condition is not known today to physicists, thus opening an avenue to constant assaults by physicians and others. Such criticisms are quoted repeatedly to the discredit of this branch of the engineering profession and to the business of the manufacturers and contractors.

Next in order will be a scientific determination of heat losses by the use of various materials employed in building construction.

Then will be investigated the efficiency of various kinds of radiation and the proper place to locate radiation to secure the best and most efficient results in different types of buildings.

The most efficient methods of burning different kinds of coal in different types of boilers and furnaces, warm-air furnaces, and furnace heating, pipe sizes for steam and water mains, and hundreds of other subjects will be investigated.

Many manufacturers have made a practice of conducting private investigations to develop their apparatus to the point of commercial perfection which is to them most desirable, finally submitting their products to the experimental laboratory of some prominent university so as to gain an endorsement having some semblance of impartiality. This never succeeds in convincing the public, as there is no comparison with other makes of the same apparatus, nor does this method establish any standard by which to measure the performance of the apparatus tested. Hence the time and expense thus employed are usually poorly invested if not entirely wasted.

This project is of such importance to every manufacturer, contractor, jobber and specialist in the heating and ventilating field that it should receive his unqualified approbation and financial support. It is a big undertaking and will entail a heavy expense for several years. The financial support of every manufacturer and engineering organization must therefore be enlisted, and such financial support must be supplemented by the personal support of every one concerned.

ARTHUR M. GREENE, JR.,
Chairman Research Committee

A—Research Results

Apparatus and Instruments A5-19 Wire-Testing Extensometer. An extensometer for testing wire and other thin sections has been developed at the laboratory of the Westinghouse Electric and Mfg. Co. It consists essentially of a metal block to which two flexible side pieces are attached, the free ends of these carrying rollers. The wire to be tested is clamped at the block and passes between the rollers. Extensions of the wire between the block and rollers due to loading the wire result in rotation of the rollers, which are held in contact with the wire by the flexibility of the side pieces.

Light from a small, straight-filament galvanometer lamp passes through a collimating lens to a mirror in the axis of one roller. From there it is reflected to a similarly placed mirror on the other roller, and reflected from there to a white scale divided into millimeters. An extension of approximately 0.0001 in. causes a movement of the spot of light to a distance of 1 mm. on the scale. The position of the spot of light could be read to 1/5 mm.

The instrument has been in constant use over a period of several months with very satisfactory results. Specimens have been tested having sectional areas ranging from one-tenth to twenty-millionths of a square inch, with satisfactory results. A patent application has been made covering this instrument. Address, Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa.

Apparatus and Instruments A6-19 Standard Cement Sample 46-c for checking 200-mesh sieves has been prepared and is ready for distribution. 80.2 per cent passes this sieve. Obtainable in 160-gram samples at the Bureau of Standards for 25 cents per sample; one sample sufficient for three tests. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A7-19 Picnometer. A new type of picnometer for the determination of density of viscous substances. Viscous liquids, such as molasses and oils, owing to their high viscosity retain innumerable air bubbles. This fact makes accurate determination difficult. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A8-19 Lime Investigations. A plasticimeter designed to determine the plasticity or spreading properties of lime has been developed by the Bureau of Standards. This simulates the action of the plasterer in spreading the material on the wall. Means are provided for obtaining the effort which the plasterer must exert and for varying at will the base upon which the plaster is spread, the time required and the angle which the trowel makes with the surface. The force required to spread the plaster in conjunction with the time during which this force acts gives the measure of the plasticity. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A9-19 Gas-Engine Indicators. Comparison tests between three types of compression indicators show that one type varies from 15 to 30 per cent from two more accurate types which agree with each other. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A10-19 The Measurement of Radii of Profiles. A communication (B519) from the Gage Section of the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A11-19 The Micrometer Microscope and Its Use in Gage Inspection. A communication (B521) from the Gage Section of the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments A12-19 The Measurement of Taper Gages. A communication (B522) from the Gage Section of the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Boilers A1-19 Boiler Treatment. Technical Paper 3218 of the Bureau of Mines. Address Van H. Manning, Director. Washington, D. C.

Calorimetry, Pyrometry, Thermometry, A1-19 Combustion of Volatile Oils in Bomb Calorimetry. A new method of burning volatile oils in a bomb calorimeter as a check on the results from a Junker Calorimeter. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Calorimetry, Pyrometry, Thermometry A2-19 Naphthalene and Benzoic Acid Samples. The Bureau of Standards has prepared new samples of naphthalene and benzoic acid to be distributed as standard heat samples, and the heats of combustion have been determined. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A6-19 Fire Tests of Reinforced-Concrete Columns. Tests indicate that columns of gravel aggregate largely of quartz or quartz and granite showed a strong tendency to spall when subjected to fire, especially with spiral reinforcement. One inch of plaster cement with light metal binder formed almost complete protection. This suggested metal-lath forms, using the concrete which passes the form as plaster. With coarse aggregate little material squeezes out. Three columns were tested in May, in two of which cement plaster was used as protection, while in a third cast tiles of gypsum were used. The outer coat of cement plaster did not remain in place under fire. The inner coat did not give sufficient protection. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A7-19 Hardeners for Concrete Floors. At the end of six months' exposure to ordinary laboratory traffic, the applications of magnesium fluosilicates, varnishes and paints, wax preparations, sodium silicate, linseed oil and soap solutions were successful. A solution of commercial sodium silicate seems to be as effective as most of the expensive preparations. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A8-19 Stucco Specifications. A tentative stucco specification has been prepared for the Committee on Treatment of Concrete Surfaces of the American Concrete Institute. It will be published in their Proceedings for 1919 and in a Technologic Paper of the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A9-19 Calcium Chloride Corrosion Tests. Plaques of 1:2 mortar and 1:3 mortar in which plain and galvanized wire mesh had been imbedded were broken during May at the Bureau of Standards when two years old. Plaques were made without using calcium chloride in mixing water and with 4 per cent calcium chloride. The mesh, both plain and galvanized, where imbedded in 1:2 and 1:3 mortar without the calcium chloride was found to be practically free from corrosion. A 1:3 mortar to which calcium chloride was added had the galvanized mesh badly rusted and the plain mesh disintegrated. The mesh in the 1:2 mortar was attacked, but not to such an extent as that in the 1:3 mortar. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A10-19 Unsoundness of Lime Plaster. To prevent unsound lime plaster with its resulting popping, the plaster sand should not contain over 1 per cent of sodium chloride, 2 per cent of magnesium chloride, and 10 per cent of red clay. Inferior quality of clay is responsible for popping. The expansion of small particles of plaster is the cause of this. The experiments have not been completed, but these results are now evident. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Chemistry, General and Physical A1-19 Applications of Critical Solution Temperature Methods. Application of method to determine purity of chemical substances. When two

substances form two liquid layers, the highest temperature at which they can exist and the concentration at this point are the critical solution temperature and critical concentration, respectively. This fixed temperature in any particular case is greatly changed by small quantities of certain impurities. This phenomenon is being applied to the following problems:

1 Determination of the composition and constituents of petroleum products, especially gasoline

2 The quantity of water absorbed by gasoline, transformer oil and other liquids which do not mix readily with water

3 The miscibility relations of the alcohols and hydrocarbon mixtures such as kerosene, as bearing on the utilization of the higher-boiling hydrocarbons as internal-combustion-motor fuels.

Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Dyes and Textile Chemistry A1-19 Ink Tablets and Powders. Analysis of a large variety of permanent inks and powders for important records. Bureau of Standards is in a position to make valuable suggestions to manufacturers and Government agencies. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electricity, General A2-19 Ignition of Cotton by Static Electricity. The Bureau of Standards has determined that the discharge from a static machine will ignite cotton under certain conditions of humidity, voltage and spark frequency, and that electricity is generated by rubbing dry cotton over a galvanized surface. Experiments were carried on because of considerable fire loss in cotton-ginning districts. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electric Power A3-19 Relative Capacities of Plates of Storage Batteries. The relative capacity of positive and negative plates are compared, showing material improvement at slight additional cost when plates are of different capacities. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electric Power A4-19 Impurities in Acid Electrolytes. Batteries affording poorest electrical performance contain largest amount of impurities in electrolytes. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Fuels, Gas, Tar and Coke A2-19 Motor-Gasoline Properties. Laboratory methods of testing and practical applications. Technical Paper No. 214 of the Bureau of Mines. Address Van H. Manning, Director, Bureau of Mines, Washington, D. C.

Fuels, Gas, Tar and Coke A3-19 Gas-Standards Investigation. Report of a Committee to the Public Service Commission of Indiana regarding the heat value of gas to be expected from gas plants using various grades of coal. Address Public Service Commission of Indiana, Indianapolis, Ind.

Glass and Ceramics A1-19 Joints of Glass to Metal. Platinized glass tubes fused into metal tubes will hold pressure up to 3000 lb. per sq. in.; capillary tubes to 6000 lb. per sq. in. Application to laboratory work in connection with glass bulbs and small valves for weighing liquid ammonia, carbon dioxide, and ethyl chloride. Used in determining gas densities by condensing gas and inclosing it within glass bulbs, and in determining the density of volatile liquids and liquefied gases for purification of gases at high pressure. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Glass and Ceramics A2-19 Heat Transfer by Radiation. Tests of plain, ribbed and hammered window glass used for greenhouses show that for a total rise of 50 deg. in temperature, the temperature rise in a given time was the same for all three within 1½ to 2 deg. cent. Aside from screening of plants from the direct sunlight, there is no apparent advantage in the use of special glass. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Glass and Ceramics A3-19 Glasses for the Protection of the Eyes from Injurious Radiation. Technologic Paper No. 119, on The Ultra-Violet and Visible Transmission of Protective Eyeglasses, discusses the results of the visible and ultra-violet transmissions of 82 samples of eye-protective glasses; the infra-red transmission having been covered by an earlier paper. Information is given regarding the approximate color, thickness, transmission between specific wave lengths compared with transmission of a sample of colorless crown glass and with the visibility or sensitiveness curve of the average human eye. The total light transmission is also given. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Internal-Combustion Motors A1-19 Deterioration of Spark-Plug Electrodes. Three phenomena appear to contribute to the sharp fractures which occur in several of the slide or "ground" electrodes of spark plugs: First, selective oxidation along the crystal borders with the formation of eutectic-like network; second, overheating and sudden cooling of one spot by spark gives rise to an intercrystalline network of fissures; third, tension on the hot wire will break it with a very low load with definite transverse intercrystalline cracks. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Internal-Combustion Motors A2-19 Radiator Investigations. Determinations of drop in pressure through air tubes of radiators show that smooth, clean and polished surfaces give higher efficiency than rough or corroded surfaces. The effect of indirect cooling surfaces and the effect of water speed on radiator efficiency have been determined. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Internal-Combustion Motors A3-19 Flame Propagation in Internal-Combustion Engines. The rate of flame propagation in engine cylinders is being measured at the Bureau of Standards, more than 150 individual photographic records being taken. The average value of this rate for aviation gasoline in engine cylinders is 10 meters per second under normal conditions. A velocity of 2.5 meters per second is obtained with lean air-fuel mixture. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Metallurgy and Metallography A6-19 The Microstructure of Very Low-Carbon Steel. Very little information is available regarding the structures which may be produced in steel containing but a few hundredths of one per cent of carbon. W. J. Brooke and F. F. Hunting (*Journal of the Iron and Steel Institute*, 1917, No. 2, p. 233) report an unusual structure found in Armco iron quenched from between 899 and 832 deg. cent. They offer the explanation that it is a eutectoid thrown out of solution between these temperatures. A study was made at Yale University, under the direction of Prof. C. H. Mathewson, to throw some light on the nature of this constituent and to determine the effect of various forms of heat treatment on the structure of very low-carbon steel. The material used was prepared by Dr. T. D. Yensen at the Westinghouse Research Laboratory by fusing electrolytic iron and carbon in a vacuum furnace. A series of exceptionally pure steels was thus made, with the carbon content ranging from 0.02 to 0.100. It was found that the "eutectoid" structures could be produced in this pure material by quenching from within the critical range. Further experiments produced conclusive evidence that the so-called eutectoid is not caused by impurities in the metal, but represents the transformation product of the austenite which is stable at the temperature of quenching.

When very low-carbon steel is quenched from above A_3 a large amount of free ferrite is found, the carbon being present in the form of sorbitic needles scattered throughout the material in the cleavage planes of the original austenite. Annealing at a temperature just below A_1 for a long period of time brings about a separation of the

sorbite needles into minute globules of cementite. Heating to just above A_1, followed by slow cooling, changes the sorbite into very small grains of pearlite uniformly distributed between the small ferrite grains. R. E. Bedworth. Address Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

Paints, Varnishes and Resins A1-19 Specifications for Linseed Oil. Circular No. 82, Recommended Specifications for Linseed Oil, has been issued by the Bureau of Standards, this being the first of a series of paint specifications based on recommendations of a Committee composed of representatives of various Government organizations purchasing such materials. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Properties of Engineering Materials A2-19 Mechanical Properties of Materials. The Bureau of Standards has issued a 51-page circular letter giving the various properties of engineering materials such as iron, steel non-ferrous metals, rubber, leather, rope and wood from latest information. The properties include density, specific gravity, tensile and compressive strengths, elongation and reduction of area, modulus of elasticity, modulus of rupture, shearing and transverse strength, ductility, Brinell and scleroscope hardness. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Sugar A1-19 Sugar Technology. An investigation of the method of analysis of sucrose or cane sugar in the presence of other sugars has been completed. The polariscope is unable to differentiate between sucrose and other sugars. As a single observation merely gives the effect of all sugars in the solution, double observations are required in which all substances except sucrose remain unaltered, inversion being brought about by heating with acid. The constants upon which the method which has been hitherto widely used was founded have been found to be considerably in error. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Sugar A2-19 Density of Viscous Liquids. See *Apparatus and Instruments A7-19*. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

B—Research in Progress

Aircraft B1-19 Fuselage Shapes. Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B2-19 New Wing Sections. Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B3-19 New Types of Gasoline Pumps. Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B4-19 New Types of Turbine Propellers with Special Characteristics as Constant Power at Various Air Speeds. Curtiss Engineering Corporation, Garden City, L. I.

Aircraft B5-19 Resistance of Flags. Address Curtiss Engineering Corporation, Garden City, L. I.

Apparatus and Instruments B10-19 Design of Aerodynamical Balance of New Type. Address Curtiss Engineering Corporation, Garden City, L. I.

Apparatus and Instruments B11-19 Experimental Determination of Influence of Air Conditions at High Altitudes on Indication of Air Speed Meters of Venturi and Pitot Types. Wind tunnel used under reduced air pressure. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments B12-19 Orifice Gas Meters. An investigation of orifice meters to correlate and verify the work of previous investigators. Coefficients to be determined are of fundamental importance in establishing accuracy of measurements of steam, natural gas and other gases. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments B13-19 Weather Tests of Building Stone. The Bureau of Standards is endeavoring to perfect an automatic freezing apparatus which will give a disintegrating effect comparable with weather conditions and at the same time facilitate the process in the laboratory. The indications are that it will be possible to produce as much disintegration in a few weeks in the laboratory as would occur in several years' exposure to the weather. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials A9-19 Expansion and Growth of Marble and Limestone. The thermal expansion of marble has been examined at the Bureau of Standards and the tendency to increase its dimensions permanently following successive heatings has been shown to be true. Experiments are being carried out to determine the amount of this growth for different types of marble and also to determine if it is appreciable for the ordinary diurnal temperature changes. Some slabs of marble 6 ft. long are exposed to the weather and measured each month. Tests are also being conducted on Indiana limestone. An examination was made on a marble floor which had been cracking. It is believed that this is due to the gradual growth. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials B10-19 Volume Changes in Cement Mortars. Continuation of work of previous months. Measurements are being made of slabs of cement mortar with the same mix of cement and sand but with 12, 13, 15, 16 and 18 per cent of water. The indications are that with the same mix and the same amount of water the contraction is the same although the slabs are made under different conditions of temperature and atmospheric humidity. Usually the contraction is greater with a larger amount of water. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Cement and Other Building Materials B11-19 Oil Storage in Concrete Tanks. The Bureau of Standards is examining concrete in connection with oil storage. So far lard oil and cocoanut oil are the only oils which have attacked concrete. After one year the surface of the concrete of the tank containing lard oil has disintegrated. After one year specimens of concrete stored in various oils and under normal conditions give the same compressive strengths. A paper presenting the results of these investigations was read before the annual meeting of the American Concrete Institute. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Chemistry, Inorganic B1-19 Spectroscopic Researches. The Bureau of Standards is investigating the spectra of many metals over a wide range of wave lengths and into the infra-red region. About fifty different elements have been investigated throughout the entire range which can be photographed by using special means of treating ordinary photographic plates so that they become sensitive to the light and to the longer wave lengths as well as the ultraviolet light. This work requires careful manipulation and skillful measurement and it is considered to be of fundamental importance. Small samples may be burned in an arc and the spectra photographed. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electrochemistry B2-19 Tests of Dry Cells and Storage Batteries. The Bureau of Standards has designed and constructed an improved apparatus to connect in the discharge circuit of batteries to be tested a selected group of cells for any period of time. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electroplating B1-19 Effect of Pickling and Plating on Properties of Steel. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electroplating B2-19 Lead Plating. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electroplating B3-19 Study of Bancroft's Axioms as Applied to Electroplating. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Electric Power B3-19 Survey of Electric-Pole-Line Construction.

An investigation of present practice of pole-line construction to increase the requirements for initial strength as proposed by the Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Fuels, Gas, Tar and Coke B1-19 Gas-Appliances Investigation. The Bureau of Standards is coöperating with the Industrial Fuel Committee of the American Gas Association, studying various types of burners used in industrial applications to correct their faults and deficiencies. The proper designs of air shutter, gas orifice, and burner throat are being worked out by the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Internal-Combustion Motors B6-19 Carburetor Investigations. An investigation is being made of the effect of the pulsations in the air flow through carburetors on account of the intermittent intake on the action of the carburetor. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Illumination B1-19 Miniature Lamps. Life tests of miniature lamps are being planned. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Leather and Glue B2-19 Deterioration of Leather. Tests have been instituted to determine the effect of varying amounts of free acids on tensile strength of leather, using aging test at a fairly high temperature and also at room temperature. In the latter test the effect of light on the rate of deterioration will be studied. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Metallurgy and Metallography B3-19 Phosphorus Content of Steel. The effect of varying amounts of phosphorus on the physical properties of steel including the determination of the limits of quantities permissible in various grades. Effect of phosphorus on the microstructure of basic and acid open-hearth carbon steel after various heat treatments. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Metallurgy and Metallography B4-19 Magnetic Analysis of Steel. The study of the possibility of correlating the magnetic and mechanical properties of steel with the ultimate object of developing methods for testing the quality and homogeneity of steel articles without injuring the specimens. Papers discussing the application to ball-bearing races and rifle barrels have been prepared. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Non-Ferrous Metals B1-19 Pure Aluminum. It has been deemed advisable to produce and determine the properties of pure aluminum. A special furnace has been constructed for this purpose and especially to eliminate the active impurities of silicon and iron. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Oils B1-19 Color Grading of Cottonseed Oils. Specific recommendations of color grading of cottonseed oils have been submitted to the Society of Cotton Products Analysts by the Bureau of Standards. Coöperative work is being carried on. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Pumps B1-19 Pump Valves. The Bureau of Standards is coöperating with two rubber companies and an insurance laboratory representing a Committee on Rubber Products of the American Society for Testing Materials in conducting hardness tests on pump valves, using the plastometer and scleroscope to determine a standard specification for hardness so that this property may be suitably related to temperature and pressure. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Railroad Rolling Stock and Accessories B3-19 Braking Stresses in Chilled-Iron Car Wheels. An investigation of stresses occasioned by braking. Results obtained so far show a marked difference in behavior of wheels of different designs and weight. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Sugar B1-19 Sugar Technology. A preliminary study of the problems of clarification of sugar liquors by other means than the sugar-filtration processes now used. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

D—Research Equipment

Aircraft D4-19 Wind Tunnel of the Bureau of Standards. The wind tunnel of the Bureau of Standards has been completed and investigations have shown that in the working section of the flow at 75 miles per hour is the lines parallel to the channel axis. The velocity at any point was not more than 0.5 per cent from the mean. Air speeds of 150 miles per hour have been attained. Power for this speed is 60 hp. Alterations just completed permit speeds of 180 miles per hour. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments D6-19 Charpy Impact Machine at the Watertown Arsenal. The Charpy impact machine consists of a pendulum of known weight swinging freely on an axis of suspension, the pendulum having the following constants:

Weight of breaking mass (pendulum)	96.370 kg.
Height of fall of center of gravity (max.)	3.1558 m.
Radius of center of gravity	1.627 m.
Angle of fall corresponding to H (max.)	160 deg.
Distance of axis of suspension from middle of impact	2.00 m.
Radius of center of percussion	1.8229 m.
Velocity of shock	7.858 m. per sec.
Theoretical work of fall (PH)	304.124 m-kg.

The principle of operation of this machine is that when the kinetic energy of the pendulum is at a maximum, the specimen to be broken is struck by the pendulum. The energy absorbed in breaking a given specimen is determined by substracting from the known kinetic energy of the pendulum at the instant of impact, the kinetic energy remaining in the pendulum after the specimen is broken. The residual energy after the specimen is broken is determined by measuring the angle through which the pendulum swings after striking the specimen.

Two types of test can be carried out on this machine, namely, transverse and tensile tests. A specimen which is to be broken by a transverse shock is supported at each end on an anvil at the lowest point of swing of the pendulum, and is struck midway between the points of support. The specimen is 16 cm. long and 3 cm. square. A slot is cut in the specimen on the opposite side from the point of impact so as to leave a sectional area to be ruptured exactly 3 cm. by 1.5 cm.

A tensile specimen can be made with or without a notch, but in any case the area of rupture is maintained at 0.2 sq. in. so that direct comparisons can be drawn between the static tensile test and the impact tensile test. The "excess angle," or in other words the angle which enables the measuring of the residual energy of the pendulum, is measured by means of a pointer and dial fixed to the axis of suspension.

From the observed readings of the excess angle at the time of rupture, and the above constants of the machine, the total amount of energy absorbed may be calculated, taking into account the energy absorbed by mechanical friction and the resistance to the air.

The large Charpy machine (Fig. 1) differs from the small machine by having a motor fastened directly to the pendulum supports for raising the pendulum, and furthermore it is equipped with a ratchet brake so as to bring the pendulum quickly to rest after a specimen is ruptured. United States Arsenal, Watertown, Mass., Address Commandant.

Apparatus and Instruments D7-19 Standard Cement Sample 46-*e* for checking 200-mesh sieves has been prepared and is ready for distribution. 80.2 per cent passes this sieve.

Obtainable in 160-gram samples at the Bureau of Standards for 25 cents per sample, one sample for three tests. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments D8-19 Picnometer. A new type of picnometer for the determination of density of viscous substances. Viscous liquids such as molasses and oils owing to their high viscosity retain innumerable air bubbles. This fact makes accurate determination difficult. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Apparatus and Instruments D9-19 Lime Investigations. A plasticimeter designed to determine the plasticity or spreading properties of lime has been developed by the Bureau of Standards. This simulates the action of the plasterer in spreading the material on the wall. Means are provided for obtaining the effort which the plasterer must exert and for varying at will the base upon which the plaster is spread, the time required, and the angle which the trowel makes with the surface. The force required to spread the plaster in conjunction with the time during which this force acts gives the measure of the plasticity. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

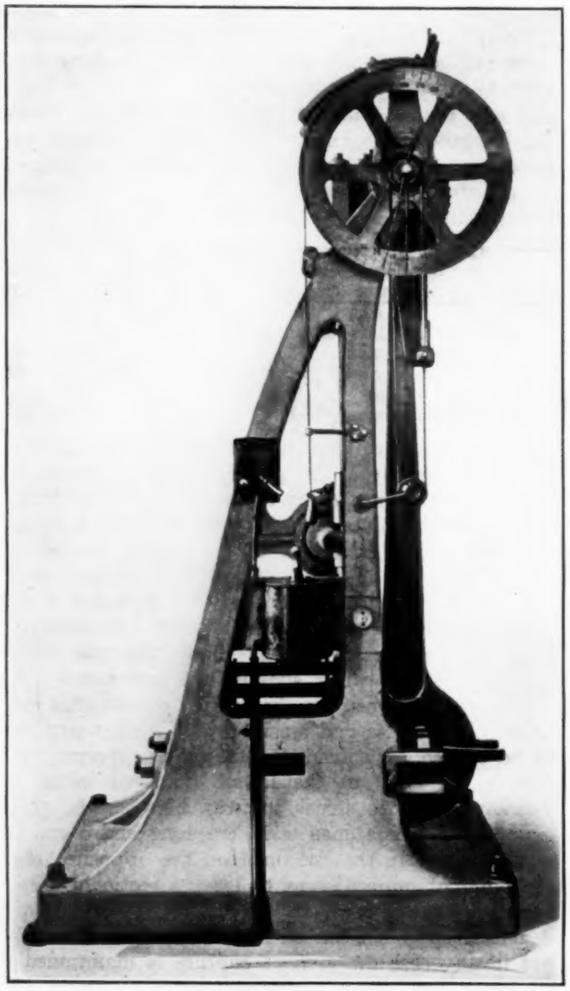

FIG. 1 CHARPY IMPACT-TESTING MACHINE AT THE WATERTOWN ARSENAL

Apparatus and Instruments D10-19 The Micrometer Microscope and Its Use in Gage Inspection. A communication from the Gage Section of the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Calorimetry, Pyrometry, Thermometry D1-19 Naphthalene and Benzoic Acid Samples. The Bureau of Standards has prepared new samples of naphthalene and benzoic acid to be distributed as standard heat samples, and the heats of combustion have been determined. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director of the Bureau.

Metallurgy and Metallography D4-19 New Furnace Equipment. The Bureau of Standards has recently installed a Héroult type of electric smelting furnace of 600 lb. capacity. It has an electrically heated crucible furnace of 70 lb. capacity; also an oil-fired reverberatory furnace for cast iron and brass of 300 lb. capacity. A new type of electrically heated muffle furnace for heat-treatment operation is being installed. A Northrup-Ajax high-frequency electric furnace melting about 10 lb. of iron has been installed. It is used for the preparation of pure metal alloys in vacuo. The Bureau is equipped to roll and forge this metal. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

E—RESEARCH PERSONNEL

Calorimetry, Pyrometry, Thermometry E1-19 Naphthalene and Benzoic Acid Samples. The Bureau of Standards has prepared new samples of naphthalene and benzoic acid to be distributed as standard heat samples, and the heats of combustion have been determined. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Properties of Engineering Materials E1-19 Mechanical Properties of Materials. The Bureau of Standards has issued a 51-page circular letter giving the various properties of engineering materials such as iron, steel, non-ferrous metals, rubber, leather, rope and wood from latest information. The properties include density, specific gravity, tensile and compressive strengths, elongation and reduction of area, modulus of elasticity, modulus of rupture, shearing and transverse strength, ductility, Brinell and scleroscope hardness. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

F—BIBLIOGRAPHIES

Air F3-19 Pneumatic Conveying of Sand, Gravel, Crushed Coal, etc. A bibliography of 1¼ pages. Search 2647. Address A. S. M. E., 29 West 39th St., New York.

Aircraft F1-19 Standardization in Aeroplanes. A bibliography of 2 pages. Search 2475. Address A. S. M. E., 29 West 39th St., New York.

Economics F3-19 Standardization. A bibliography of 2 pages. Search 2500. Address A. S. M. E., 29 West 39th St., New York.

Properties of Engineering Materials F1-19 Relation Between Hardness and Machinability. A bibliography of 1¼ pages. Search 2629. Address A. S. M. E., 29 West 39th St., New York.

Correction to Paper on Present Condition of Research in the United States

In preparing my Spring Meeting paper on The Present Condition of Research in the United States and in reading the proof I failed to realize that I had made a misstatement in attributing the laboratories at Pittsburgh and Washington to the United States Geological Survey. [See MECHANICAL ENGINEERING, July 1919, p. 588.] These laboratories should be attributed to the Bureau of Mines. In writing this paper and in reading proof I did not notice this error, although the statement was not due to misinformation or lack of knowledge on my part.

ARTHUR M. GREENE, JR.

ENGINEERING SURVEY

A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

SUBJECTS OF THIS MONTH'S ABSTRACTS

AERONAUTICS (See also Internal-Combustion Engineering)

Monoplane vs. Biplane, Grover C. Loening. An argument for the monoplane by the inventor of the first monoplane bought by the United States Government.

There is no question as to the monoplane being the simplest type of machine (having only one set of wings and ailerons) and the lightest type, in that the wing structure itself for any given weight can carry more load than a biplane. The ordinary biplane, however, has two serious defects: (1) lack of strength, particularly against twisting and drift stresses; and (2) a bad range of vision. These objectionable features are claimed to have been eliminated in the Loening biplane, which puts it on a footing of equality with, and perhaps makes it preferable to biplanes for certain purposes.

To maintain the strength against drift and a general rigidity to the wing structure against twisting stresses, the monoplane wing is braced rigidly by large struts at a good angle in much the same way as the overhang section of some biplanes.

As regards the bad range of vision in the Loening monoplane the following structure has been adopted. Instead of raising the wing above the body parasol fashion, the pilot is seated low—so low that his eyes are on a level with the wing—and the side of the fuselage is open on either side of him. In such a position the motor in front shuts off the view forward, but in the Loening monoplane the body is so narrow in front that the pilot by shifting his head a little can see ahead of him on either side.

The author frankly recognizes this as a trick of construction, but states that it had much to do with giving this particular type of monoplane the range of vision which it has been found to have.

Aerodynamically, it is claimed that the centers of thrust, weight, head resistance, etc., have actually by test been found to be every bit as good in the monoplane as in the biplane. The only distinction is that the center of thrust on the monoplane is but a small distance below the wing, and the action of the spiral slip stream of the propeller in washing itself out against the wing results in neutralizing the torque of the motor. Thus no correction whatsoever is made in the wing alignment for the torque and the motor can be thrown on and off without affecting to any noticeable degree the balance and stability of the machine.

Further, on the monoplane a very large and definite area of the wing rides in the slip stream of the propeller under a most efficient condition. The proportional increase in lift so derived is considerable. Actual test has shown that the monoplane with a load of 11 or 12 lb. per sq. ft. will be as buoyant and land as well as the biplane with a load of about 7½ lb.

In fact, the author looks forward to the possibility of having large monoplanes with a 20- or 25-ft. chord carrying 18 or 19 lb. per sq. ft. at a low speed. (*U. S. Air Service*, vol. 2, no. 1, August 1919, pp. 25-27, *tc*)

CORROSION (See Engineering Materials)

ENGINEERING MATERIALS

Corrosion Phenomena in Non-Ferrous Materials

Effect of Corrosion on Wrought Manganese Bronze Under Tensile Stress, P. D. Merica and R. W. Woodward. An investigation to determine what service stresses may with safety be applied to physically normal wrought brass and bronze, and the types ordinarily used for structural purposes.

In the course of a previous investigation by the authors of a series of failures of brass and bronze bolts by fracturing, it was suspected that many cases of such failures were not due to defective material but to the fact that the bolts had been overstressed in service.

An investigation has shown that brass rods exposed to the action of concentrated ammonium hydroxide and subjected at the same time to the very gradual application of tensile stress would break with little elongation at any values of the stress greater than the yield point of the material. From this it appears that the effect of combined tensile stress and surface corrosion is to decrease the stress at which fracture will occur.

This matter is of considerable importance. Brass and bronze usually take the place of steel only because of their supposed superior resistance to corrosion, and if it were proven that such superior resistance is not as great as hitherto assumed, the usefulness of brass and bronze for structural purposes would be very largely limited.

The paper describes in some detail the method of carrying out the tests and making the measurements. The period of exposure was two years, which is relatively short in comparison with the periods for which such materials may actually be used in service. Furthermore, the test bars used were given a low-temperature anneal in order to relieve the initial stresses and consequently their behavior may differ during test from that of brass in which the stresses still remain. Therefore, as pointed out by the authors themselves, any conclusions to be derived from the results given in the paper must be regarded as quite restricted in their definite application and as more or less tentative in their more general aspects.

The general conclusion seems to be that brass or bronze might not be subjected to corrosion (in ammonium hydroxide) while under a tensile stress greater than 20,000 lb. per sq. in. or greater than 5000 lb. per sq. in. above the yield point without danger of failure.

The authors' tests indicate that the proportional limit is to be regarded as the maximum safe stress for manganese bronze of harder tempers, but that it is not certain that this limit may not be slightly exceeded in materials which are soft, that is, free from work hardness. (Paper presented at the Annual Meeting of the American Society for Testing Materials, June 24-27, 1919. Com-

pare *American Machinist,* vol. 51, no. 5, July 31, 1919, pp. 217-220, *ep*)

Mechanical Properties and Resistance to Corrosion of Rolled Light Alloys of Aluminum and Magnesium with Copper, Nickel and Manganese, P. D. Merica, R. G. Waltenberg and J. R. Freeman. The paper is summarized by the authors as follows:

Light aluminum alloys of several compositions belonging to each of the three ternary series, aluminum-magnesium-copper, aluminum - magnesium - manganese, and aluminum - magnesium-nickel, were rolled out into sheets and tested in tension as cold-rolled, after annealing, and after heat treatment consisting of quenching from about 500 deg. cent. and aging at ordinary temperature.

The tensile properties of the alloys of the aluminum-magnesium-copper series were superior in all conditions to those of the other series. They may be much improved by an appropriate heat treatment. The alloys of the aluminum-magnesium-nickel series are also improved by heat treatment, but not in the same degree as the former series. The alloys of the aluminum-magnesium-manganese series are not improved by heat treatment.

Samples of representative compositions of each series were exposed to corrosion in the salt-spray test, and the appearance of the samples observed after exposure to the action of the salt spray for one and for two months. The alloys of the aluminum-magnesium-manganese series resisted corrosion, in general, better than those of the other series, and this observation agrees with other experience in the corrosion of such alloys. The heat-treated specimens of the aluminum-magnesium-copper series, however, were but little inferior to those of the manganese series in their resistance to corrosion; the annealed and the cold-rolled samples of that series were the least resistant to corrosion of any of the alloys tested. Hard-rolled commercial aluminum corroded much more than any of the alloys. Annealed aluminum was more resistant to corrosion than the hard-rolled aluminum, but did not compare favorably with most of the alloys. (*Bulletin of the American Institute of Mining and Metallurgical Engineers,* no. 151, July 1919, pp. 1051-1062, *e*)

Variation of Physical Properties of Test Pieces with Age After Machining

Effect of Time and Low Temperature on Physical Properties of Medium-Carbon Steel, G. A. Reinhardt and H. L. Cutler. Data based on the experience of the Youngstown Sheet and Tube Company in making acceptance tests of medium-carbon steel.

This company produced a large tonnage of 0.35 to 0.45 carbon forging steel, the acceptance of which was based on the physical properties of test specimens obtained by forging the original 5.75-in. square bloom to 0.75-in. round. No difficulty was experienced in meeting the specifications called for.

Soon after, production of slightly higher-carbon forging steel was started. The method of testing this material required that test blooms be either normalized or annealed. The normalizing consisted in heating to 850 to 900 deg. cent. and cooling in still air; the annealing in heating to the same temperatures and cooling in the furnace or mica. From the treated bloom the test pieces were taken either by core drilling or by sawing from joints midway between the edges and the intersection of the diagonals. The cores or blocks were turned to a standard 2-in. test piece with a diameter of 0.564 in. and tested without further treatment.

Difficulty was encountered as soon as work on this material was started. Many precautions and refinements were instituted, but it was found very difficult to secure the required elongation. Still a very good chemical analysis was produced. Great care was taken during the heating and rolling as well as in heat-treating and machining the test pieces, but none of these precautions helped in producing uniform results, although occasionally the results were very good.

A careful examination disclosed the fact that invariably these good results were obtained from test pieces that had been machined the day before they were tested. The experience of several other men in and out of the company showed the similar behavior of rail-steel test pieces. As a result, it was decided to rest all pieces over night and test them the following day. As soon as this practice was adopted the difficulty in heating the elongation requirement of the specification disappeared.

Since it was at times undesirable to hold a shipment long enough to afford a 24-hr. rest for the test pieces, experiments were made, and it was found that a rest of a few hours at about 120 deg. cent. was equal to a 24-hr. rest at room temperature.

A series of tests were also made to determine the cause for the great difference in elongation and reduction of area shown by test pieces which had or had not periods of rest. The cause of this was not found, but some interesting data were collected.

This series of tests showed that a slight increase in temperature during the rest period resulted in a great improvement of elongation and reduction of area. The increase in tensile strength was considerable and greater in the case of a two-day rest than in the case of a four-day rest.

Tests were also made to determine the effect of speed of machining on the physical properties of a test piece and it was found that the rate of machining has practically no influence.

A further series of tests on 16 cores showed that the elongation increased with increased length of rest at the temperature of the top of the furnace. A rest of 16 days at room temperature increased the elongation and reduction of area to about the same extent as a rest of 25 hours on the electric furnace. On the other hand, test pieces heated to 500 and 600 deg. cent. after rests of four and 16 days, respectively, tested immediately after making it, gave lower elongation and reduction-of-area values than pieces that had been rested at lower temperatures. No explanation for this is offered. On the whole, the writers come to the conclusion that the ductility of steel expressed by elongation is greatly improved by some equilibrium adjustment which takes place slowly at room temperature and much more rapidly at slightly increased temperature. It seems possible that the difference in the results obtained on tests taken from blooms and on tests taken from small billets may be due to a combination of solidification and rolling strains. (*Bulletin of the American Institute of Mining and Metallurgical Engineers,* No. 151, July 1919, pp. 1091-1098.)

Graphitization Ranges of Temperature in White Cast Iron

Graphitization of White Cast Iron upon Annealing, P. D. Merica and L. J. Gurevich. This investigation was mainly undertaken in connection with other investigations on the properties and characteristics of chilled-iron car wheels, in particular to determine the best range of annealing temperatures.

Chilled-iron wheels are cast with a chill against the thread and the inside of the flange, the remainder being in sand. The composition of the metal is so chosen that under these conditions the tread and inside of the flange will show white iron to a depth of from 5/8 to 7/8 in. (15 to 22 mm.), the remainder of the wheel becoming graphitized or gray. In order to relieve the stresses set up during cooling under such drastic conditions, the wheels are stripped from the mold, while still red hot, piled in a soaking pit, and allowed to cool very slowly from their temperature at stripping.

Obviously, the most suitable temperature for this annealing is the highest at which no formation of graphite occurs within the white tread and at which the wheels can be stripped from the molds. Inasmuch as no direct determinations have been made of the temperature at which the formation of graphite takes place in white iron of compositions used in car wheels upon annealing, it was considered worth while to determine these temperatures as a means of establishing the maximum temperatures at which the annealing of the wheels may be carried out. In the course of this work some incidental observations were made which are of interest in connection with the theory of graphitization in white iron.

The paper is summarized by the authors as follows:

The annealing or graphitization ranges of temperatures were determined for three different compositions used for car wheels.

The temperature of initial precipitation of temper carbon for six hours of annealing was not noticeably affected by variation of sulphur content from 0.10 to 0.20 per cent or by variation of total carbon content from 3.60 to 3.90 per cent, although the effect of greater carbon content is to narrow the temperature range within which graphitization is complete.

The temperature of beginning precipitation of temper carbon was about 830 deg. for the 6-hr period of annealing, and about 730 deg. cent. for the 48-hr. period. The maximum allowable temperature, therefore, for the annealing, or "pitting," of car wheels is about 730 deg. cent.

After complete decomposition of all free cementite by annealing at from 1000 deg. to 1100 deg. cent. and cooling at equal rates in a laboratory electric furnace, less graphite is found in a specimen cooled from 1100 deg. than in one of the same composition cooled from 1000 deg. cent. This indicates that graphite separates directly from solid solution upon cooling, when its nuclei are already present.

The fact that only 0.20 per cent of combined carbon was found in some specimens after annealing at high temperatures and cooling slowly in the furnace, would indicate either that the graphite eutectoid lies at much lower values of carbon content than has been previously supposed, that there is at those rates of cooling a direct precipitation of graphite eutectoid, or that there is a formation of graphite from pearlite at temperatures directly below that of its formation. (*Bulletin of the American Institute of Mining and Metallurgical Engineers*, no. 151, July 1919, pp. 1063-1072, *e*)

HYDRAULIC ENGINEERING

HEXAGONAL CHART FOR FINDING VELOCITY OF WATER IN PIPES, C. Warington Anthony. Reprint of a brief but highly suggestive article and accompanying illustrations.

Exponential formulæ are very much used nowadays in hydraulic problems dealing with the flow of water in pipes and sewers. Many charts or diagrams have been drawn to represent each formula, some taking a variable coefficient into account, which depends on the nature of the inner surface of the conduit, but the writer has never seen one made that does equally well for all the exponential formulæ. For this reason I have designed a hexagonal chart (Fig. 1) that takes care of six variable quantities—the velocity of flow, coefficient of roughness, hydraulic mean radius and slope, together with the powers to which these last two quantities are raised—and yet in spite of all this apparent complexity this chart is as easy to handle as a chart made for working out only one kind of exponential formula. Evidently a chart of his description will prove of great value, since it may be used for rapidly computing and comparing results obtained for a given case by applying different formulæ. It may also be used to deduce the best equation to fit in with the results of experiments that have actually been carried out.

The exponential formula is usually written: $V = C\ (D/4)^p S^q$, or $V = CR^pS^q$, since the hydraulic mean radius of a pipe flowing full is the fourth part of its diameter. There will be seen to be three binary scales in the chart, arranged in the form of an equilateral triangle. The coefficient and velocity go together on

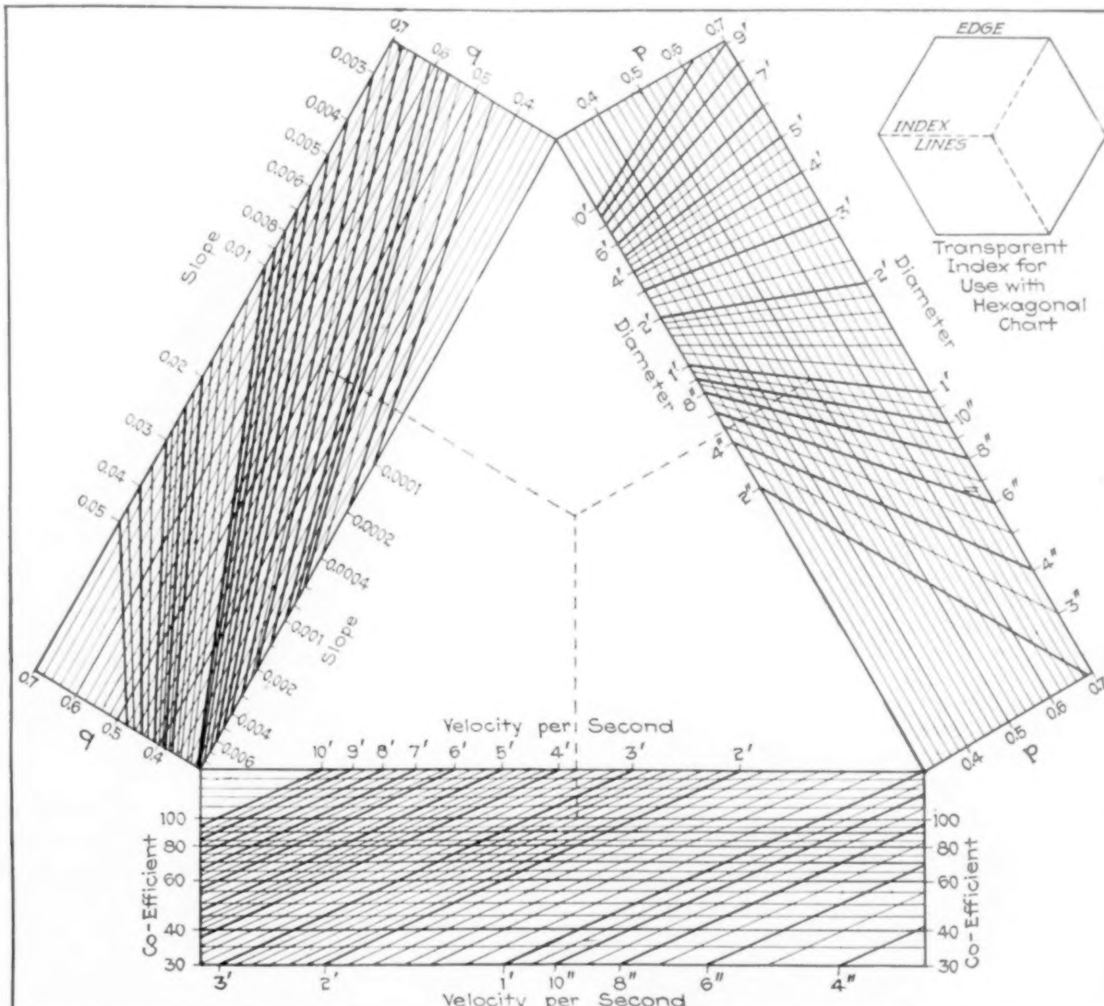

FIG. 1 HEXAGONAL DIAGRAM FOR FINDING VELOCITY OF WATER IN PIPES

one scale, and the diameter and slope, together with their respective powers, on the other two scales. The way the diagram is used is illustrated with dotted lines for the following case:

Diameter, 1 ft.; slope, 0.0025; coefficient, 100, $p = q = \frac{1}{2}$. The velocity is seen to be $2\frac{1}{2}$ ft. per sec.

When using the chart it is convenient to have a hexagonal transparent index, as shown in the upper right-hand corner of the illustration, with its sides parallel to the three index lines. By placing a straight edge against one side, the index lines may be moved without changing their orientation or displacing the one parallel to the straight edge.

The great beauty of the chart lies in the fact that it does not contain a single curve, which makes it much easier to draw and at the same time a high degree of accuracy is insured. This is attained by employing logarithmic instead of equally spaced coordinates. (*Engineering News-Record*, vol. 83, no. 4, July 24, 1919, p. 169, *tpA*)

INTERNAL COMBUSTION ENGINEERING (See also Machine Elements)

Novel Features in Oil-Engine Design

THE DOXFORD OIL ENGINE. Description of an internal-combustion engine of British construction. The engine was first built as a Diesel but has now been changed to a hot-surface type with solid injection of fuel.

As regards the latter the present arrangement is that three rams are used, the fuel pump being driven through small cranks on the camshaft set at 120 deg. so that the work may be divided over the revolution and eliminate the very heavy shock which would occur if but one ram were used. These rams force the oil into two small air vessels initially charged with air at a pressure of 1000 lb. per sq. in., the ram pressure being 8000 lb. per sq. in.

The pumps are said to be a very beautiful piece of work; so good, indeed, is the fit that no packing is required even at this enormous pressure, the leakage representing little more than an overflow of lubricant. This end has been reached by a departure from the ordinary method of driving the fuel pump. In the Doxford machine there is used a slotted crosshead with the sliding block for the driving pin to work in, the crosshead being carried in very closely fitting guides at each side. The plunger is connected to the crosshead with an ordinary union nut, so that provided the center lines are parallel, which of course can be insured, any want of exact concentricity may be allowed for, and the thrust of the ram must be absolutely axial.

The fuel valves present a new feature in that they have only a light spring to keep them on their faces when the engine is not running. The size of a spring strong enough to keep them closed against an oil pressure of 8000 lb. per sq. in. when working would be on the heavy side, but if 8000 lb. will blow the valves off their faces it will equally well keep them on, if applied to a larger diameter and that is, in fact, the plan adopted again with unpacked plungers.

The elimination of the blast air forced the use of a different arrangement of valves. Formerly the fuel was blown in by air tangentially on opposite sides of the cylinder so as to create a turbulence. With the solid jet of fuel no turbulence can be obtained, so that the fuel must be diffused as much as possible, and the valves are now arranged opposite to each other, but one above the other so as to cover as large a volume of air as possible.

One of the peculiar features of the engine is the fact that instead of attempting to keep the piston as cool as possible in this case every effort is made to allow the crown to reach a temperature of not less than 1000 deg. fahr., and it is the piston crown which forms the hot surface which really fires the charge with heavy oils. Such a high temperature is rendered possible by the special design of the piston, Fig. 2. Here *C* is the heatable cap which keeps the fire off *D*, the piston proper. *C* is a steel forging, of which the crown is some 4 in. thick and is water-jacketed on the under side. Thermocouples attached to a point a few millimeters inside the top surface showed a temperature reading of about 950 deg. fahr. at the load on which the engine was running on the occasion of the writer's visit, and a temperature of only 350 deg. fahr. at a corresponding point on the bottom surface. It will be noticed that the cap *C* only comes into contact with the actual piston *B* at the bottom where everything is well cooled, and that there is a good clearance at the sides and top and also between the cylinder liner and the edge of the forging, so that it can expand or distort to a very considerable extent without doing any harm. The water passages *D* are ribbed at close intervals, the alternate ribs having holes at the top and bottom so that the water has to take a very devious course and keeps the cast iron cool, the final outlet being from the passage *E*, which, as a matter of fact, is carried up by a tube to just under the crown and not cut off short as shown in the figure.

The engine has been running for several months and is said to completely consume Mexican oil with its very high percentage of

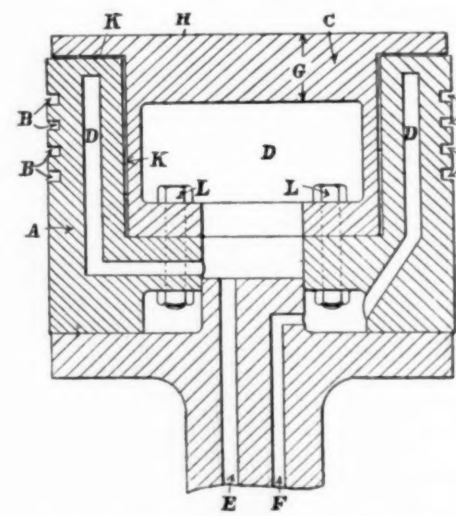

FIG. 2 PISTON OF THE DOXFORD OIL ENGINE

asphaltum, and to give an absolutely clean exhaust. The consumption is said to be 0.42 lb. per b.hp-hr.

The elimination of the high-pressure air compressor for blast injection means, of course, a saving both in fuel and first cost, weight and maintenance. (*The Engineer*, vol. 128, no. 3316, July 18, 1919, pp. 64-65, 2 figs., *d*)

Temperature Relations in an Internal-Combustion Engine Due to Presence of Residual Gases

THE EFFECT OF NEUTRAL GASES ON THE TEMPERATURE OF THE WORKING FLUID IN AN INTERNAL-COMBUSTION ENGINE. Kango Takemura. Discussion of a subject which attracted a considerable amount of attention in the early days of the introduction of the Otto cycle.

The writer believes that the neutral gases left in the cylinder at the end of the previous stroke have a considerable influence on the temperature of the new combustible charge, and gives a mathematical estimate of the rise of temperature which they effect. He uses the following notation:

Let θ_1 = temperature of the neutral gases left in the combustion chamber

c_1 = specific heat of those gases

w_1 = weight of the gases

θ_2 = temperature of a new charge, supposed to be constant and equal to that of the atmosphere

c_2 = specific heat of the charge

w_2 = weight of the charge

θ_3 = temperature of the working fluid or the mixture of the neutral gas and the new charge

c_3 = specific heat of the fluid.

An assumption is made that the new charge is drawn through the neutral or residual gases and that a temperature equilibrium is established instantaneously.

The writer derives the following equation

$$\theta_2 = \frac{\theta_1 + \theta_2 \dfrac{\theta_1 + 273}{\theta_2 + 273} \times \dfrac{.x}{.l}}{1 + \dfrac{\theta_1 + 273}{\theta_2 + 273} \times \dfrac{.x}{.l}}$$

where Θ_2 is temperature in absolute degrees and the values of θ_1 and θ_2 are in cent. deg; also $.x$ stands for x/L, where x is a portion of the stroke and L is the full length of the stroke; $.l$

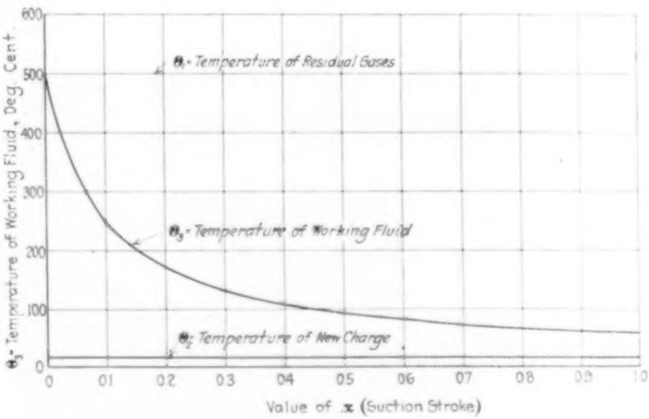

FIG. 3 RELATION BETWEEN THE TEMPERATURE OF RESIDUAL GASES AND WORKING FLUID IN AN INTERNAL-COMBUSTION ENGINE

stands for l/L, where l is the height of a "equivalent combustion chamber" on a base equal to the area of the piston. The value of $.l$ depends on the ratio of compression and is equal to 0.25, if the latter is taken at 5.

Adopting these figures the writer obtains

$$\frac{D_1}{D_2} = \frac{\theta_1 + 273}{\theta_2 + 273} = \frac{500 + 273}{16 + 273} = 2.67$$

and

$$\theta_2 = \frac{500 + 16 \times 2.67 \times 4 \times (.x)}{1 + 2.67 \times 4 \times (.x)} = \frac{500 + 170.9 \times (.x)}{1 + 10.7 \times (.x)}$$

where D_1 = density of the neutral gases at the moment when their mixing with the new charge begins and D_2 is the density of the new charge.

TABLE 1

$.x$	θ_2	$.x$	θ_2	$.x$	θ_2	$.x$	θ_2
0.1	250	0.4	108	0.7	73	1.0	57
0.2	170	0.5	92	0.8	66	...	...
0.3	130	0.6	82	0.9	62	...	...

The values of θ_2 calculated by means of the foregoing equation are given in Table 1 and shown graphically in Fig. 3. (*Journal of the Society of Mechanical Engineers*, Tokyo, Japan, vol. 22, no. 56, *tm*)

War-Time Research in Aeroplane Feuls

THE INVESTIGATION OF AIRPLANE FUELS, E. W. Dean and Clarence Netzen. Data of recent work carried out chiefly by the United States Bureau of Mines and of considerable importance not only in aviation but in the general design of automotive apparatus.

In the course of this work E. R. Hewitt showed that such fuels as benzol and alcohol did not ignite until heated several hundred degrees fahrenheit hotter than the ignition temperature of paraffin hydrocarbons. These data were of use in indicating the order of ease with which various fuel mixtures could be made to preignite in engine cylinders.

Simultaneously with this the research organization maintained by the Dayton Metal Products Company studied the relation between the nature of the fuel and the maximum compression ratio that could be maintained in an engine without interfering with smooth operations. Data of this investigation have been published quite fully elsewhere. The experiments of the Dayton laboratory have shown, however, that the chemical properties of the fuels were more important than the physical ones, and therefore a large number of fuels were collected and tested. In addition, an extensive research was devoted to the production of cyclohexane.

Attention to this fuel was particularly drawn by the reports that the Germans were using it as an airplane-engine fuel. Actually, though, there does not seem to be any evidence that this was the fact.

The engine fuel actually tested after the first few engine runs was not pure cyclohexane, but a mixture called "heeter," composed of from 70 to 80 per cent cyclohexane and 20 to 30 per cent of benzol.

Through the courtesy of the engineers at McCook Field, the Bureau of Mines obtained the loan of a testing engine made by equipping one cylinder of a standard Liberty engine with a special crankcase, shaft and flywheel (compare MECHANICAL ENGINEERING, March 1919, p. 249). A set of pistons was obtained which gave compression ratios ranging from 5.3 to 1 to 8.2 to 1. Pressures measured with an Edelman gage, with the engine turned at 400 r. p. m., varied from 113 to 185 lb. per sq. in.

A considerable number of fuels were tested with this equipment, and results obtained showing that gasoline composed of paraffin hydrocarbons had a marked tendency to knock at the 5.3-to-1 compression ratio, whereas heeter-benzol-alcohol and a special alcohol-benzol-gasoline mixture known as Taylor fuel No. 4 showed only a slight tendency to knock under an 8.2-to-1 compression ratio.

Cracked gasoline and California gasolines were intermediate in resistance to knocking, and were notably better in this respect than the paraffin-base products. This superiority is attributed to the presence of unsaturated and cyclic hydrocarbons in the cracked distillates and to cyclic hydrocarbons in the California gasoline. In some of these fuels, however, undesirable properties have been found, and as a last analysis the most promising product was found to be heeter, with California gasoline or gasoline-benzol mixtures as a second choice.

Supplementary tests were carried out on a standard Liberty engine with a full set of 12 special pistons permitting the adjustment to 70 per cent cyclohexane and 30 per cent of benzol in a DeHaviland-4 plane. The results of these tests, however, were unfavorable.

The next series of tests were tried with the same pistons on another Liberty engine, also in a DeHaviland plane. From the figures given in the paper it does not appear quite clear what the composition of the fuel was in this series of tests, the results of which were, however, favorable, the engine operating smoothly and yielding the additional power that was to have been expected on account of its high compression ratio. Similar tests in the altitude chamber of the Bureau of Standards also gave favorable results.

The comparative data obtained with the single-cylinder Liberty engine indicate where by proper selection of fuel it is possible to employ considerably higher compression ratios than the maximum now considered practical for aviation engines.

The establishment of this part is considered of importance, even if it proves that a 7.2-to-1 ratio is too high, and that heeter is not as practicable or desirable as other mixed types of fuels. (Paper before the Society of Automotive Engineers, published by permission of the Director of the United States Bureau of Mines. *Journal of the Society of Automotive Engineers*, vol. 5, no. 2, pp. 126-130, *ea*)

MACHINE ELEMENTS

Tests on Pin-Riveted Joints Made by the Schuch Process (*Zeitschrift des Vereines deutscher Ingenieure*, June 14, 1919). This article describes tests performed on riveted joints made with pin rivets according to a new process (German Patent No. 302,-269). The advantages of the new system of riveting are claimed to be: (1) Cheaper cost of rivets; (2) the rivets are more evenly heated; (3) the hammer scale is removed when the rivets are snapped home. The result is that the rivet heads do not loosen and calking is no longer necessary, thus showing a considerable saving in wages and tools, also time taken on the operation. The new form of rivet is shown in Fig. 4.

The firm of Schuch & Co., who hold the patent rights, have designed a work-controlling apparatus for hydraulic riveting machines for use in connection with the new process. This device records automatically the riveting force and the time taken in snapping a rivet.

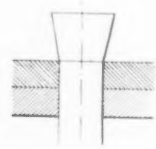

Fig. 4 Schuch Pin Rivet

A riveted joint made as shown in Fig. 5 was sent for test to the Material Test Laboratory of the Stuttgart Technical College, and the following are the conclusions arrived at:

1 The rivet heads were only very slightly warped
2 The plates suffered slight curvature or bulging
3 The plates do not show any appreciable crushing at the margings of the holes.
4 The stresses with which the rivets press the plates together were found to be about the same as with ordinary rivets.

Numerous locomotive boilers have been riveted on the new system and have given satisfaction. (*Technical Supplement to the Review of the Foreign Press*, vol. 4, no. 2, July 22, 1919, p. 45, no. 5643, *d*)

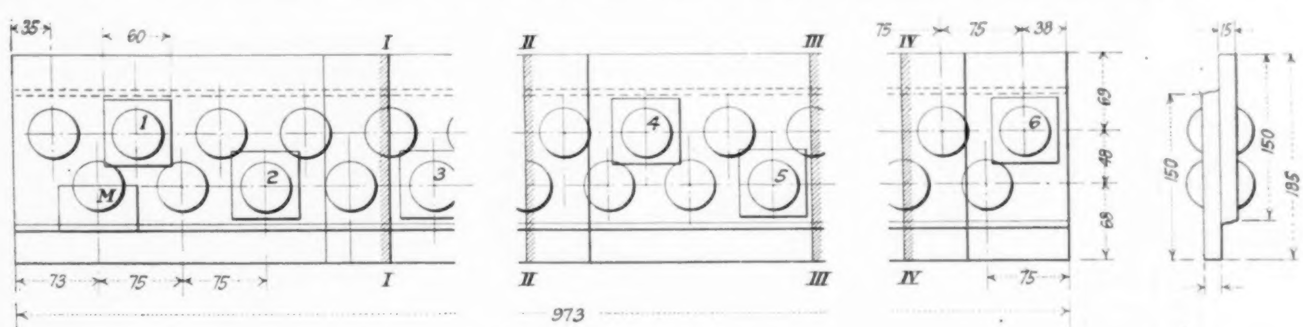

Fig. 5 Schuch Pin-Riveted Joint

Two-Part Piston Ring, Ellsworth Sheldon. Description of a piston ring manufactured by the Yale Piston Ring Company.

The ring as shown in Fig. 6 is made in two parts: the outer part of soft gray iron performing the usual function of piston rings; and an inner ring of tempered steel which furnishes the tension necessary to hold the outer part in contact with the cylinder walls and also serves to keep the ring in contact with the sides of its groove in the piston, thus preventing the leakage of gas past the piston that would occur with the ordinary form of ring as soon as the latter had worn or if it was badly fitted to the groove in the first place. It is also claimed that with this construction worn rings may be reground on their edges, the grooves faced, and the ring still retain its seal.

The outer ring resembles an ordinary gray-iron piston ring, with three differences, however. First, as the ring is not required to exert pressure of itself it may be made of the softest gray iron obtainable; second, for the same reason, the outer diameter is ground to the same size as the cylinder instead of 1/8 to 3/8 in. larger, as in the case of the snap ring; and third, the inside of the ring is not parallel with the outer surface but is bored taper or at an angle of 15 deg., so that the ring has one thick edge and one thin edge.

The inner ring is of tempered steel and is of a section complementary to the outer one, that is, its tapered or beveled surface is on the inside and when the steel ring is pushed into the gray-iron one its tension not only holds the latter against the cylinder walls, but also by reason of the two beveled surfaces coming together the iron ring is pressed against one side of the groove and the steel one against the other side, forming a sort of automatic adjustment for maintaining the width.

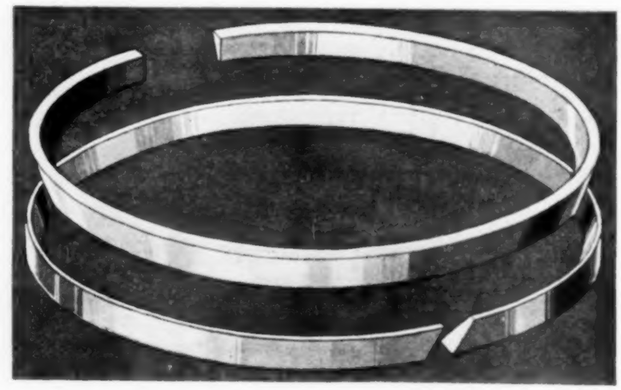

Fig. 6 Two-Part Piston Ring

The article describes in detail the method of manufacture of these rings and the tools used. Of particular interest is a machine especially designed for polishing the outer surface of the ring. As this surface is not parallel to the bore and consequently not square with the ground edges, and further as the ring being sprung open is not round, the job of polishing the outer surface is by no means simple, especially as it is necessary to maintain the bevel at a constant angle to keep the surface flat widthwise and to avoid grinding hollow spots in the contour of the ring.

In this machine a circular table somewhat larger in diameter than the largest ring to be polished is provided for each wheel, the table being supported on the upper end of a rod, which, when the machine is in operation, is given a slowly reciprocating endwise movement in a direction parallel to the axle wheel so that whatever work is held upon the table in contact with the wheel is automatically passed back and forth across the face of the latter. It is stated that by this means the tendency to wear grooves in the surface of the work is obviated.

As the ring is not round, owing to its having been sprung open to give it initial tension, it cannot be rigidly held to the wheel and the operation is therefore somewhat dependent upon the skill of

the operator to avoid grinding hollow spots on the periphery of the ring, but the men soon become experts in this work. (*American Machinist,* vol. 51, no. 5, July 31, 1919, pp. 199-202, 10 figs., *d*)

Design of Ball and Roller Bearings Subject to Centrifugal Loads

Ball and Roller Bearings, Capt. J. B. Swan, R.A.F. Data obtained from the records of the Technical Department, Aircraft Production (British) and dealing with the consideration of the behavior of ball and roller bearings when subjected to centrifugal loads.

When a ball or roller bearing is rotating as a whole about an axis without its own geometric center the condition of loading is quite peculiar, and it has been found that if the rollers or balls are above a certain size and the speed of rotation high the ordinary type of caged and uncaged bearing has a very short life. This particular type of loading is exemplified in practice when ball or roller bearings are used in big ends of connecting rods or in types of reduction gears in which the spider carrying the bearings rotates.

In a 10-cylinder radial engine developed by the Admiralty Air Department in 1916 a ball-bearing type of big end was used and as the engine was a two-throw radial, the big-end loading was necessarily high. When the engine was put into production the bearings were ruined after about five or six hours. At first it was thought that the cages for the balls were at fault and so cageless races were tried, with the result that the balls were worn with flat belts around them.

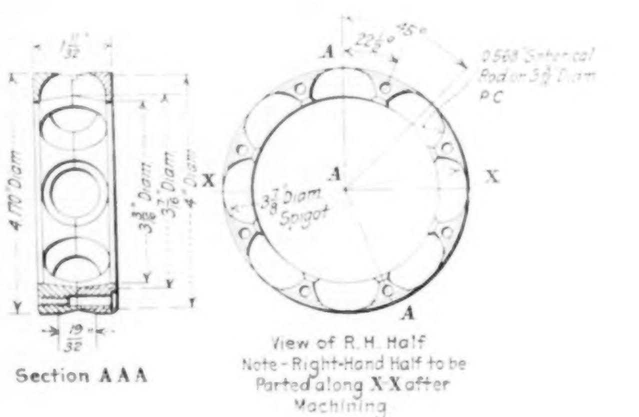

Fig. 7 Located Cage for Ball Bearings

As it was also noticed that the balls always showed the first signs of wear, it was deduced that the wear was probably due to the fact that the balls were subject to an undue crowding action which made them abrade each other, and when once the ball surface was roughened the race became speedily destroyed. This appeared to be especially so, as the load if normally applied would have been quite low for a bearing of the size used.

It appeared that as the bearing rotated about the crank center the balls, in the case of a cageless bearing, were crowded away from the center of rotation by a centrifugal force acting on them and rubbed against one another, the balls remote from the crankpin center being pressed together by the combined centrifugal force of the other balls. As the balls were rotating about their own centers at about 2500 r.p.m. and the points that touched were moving in opposite directions, the abrasive action was very considerable.

When a cage of the steel-plate type was used a similar action took place. The cage was subjected to its own centrifugal force and also to the cumulative centrifugal load of the balls which it carried. This combined load was acting in line with the crank radius but away from the crank center and caused a displacement of the cage in that direction until a point was reached when the bearing load on the balls nearest the crank center due to the cage wedging between them, was equal to the combined load on the cage and this caused a heavy abrasive action between the balls and the cage at the point of application of the mean load on the race, producing a tendency for the balls to skid on the race at this point and causing in a short time serious damage to the balls, races and cage.

The foregoing experience indicated that the function of the cage was to carry independently the rubbing loads on each ball due to the centrifugal force and to prevent abrasive action on the balls. Because of this in designing the cage the following points had to be observed:

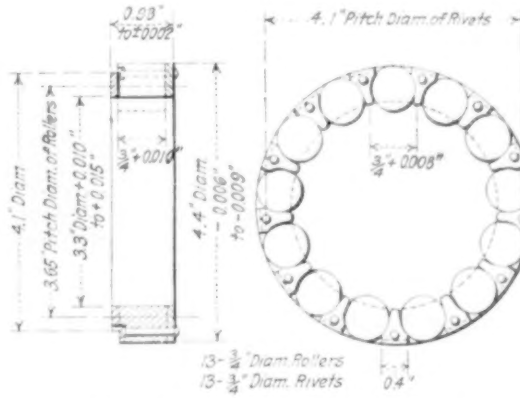

Fig. 8 Located Cage for Roller Bearings

1 The cage must be strong enough to take the independent loads from the balls without distortion
2 Sufficient bearing surface must be provided at the surface of location of the cage to carry safely the combined centrifugal load due to the cage itself and the balls
3 Ample bearing surface must be provided between the balls and the cage to prevent wear on the cage
4 The cage must be made of a metal which gives a minimum abrasive action with the steel of the ball and race and at the same time has sufficient strength
5 All surfaces must run with a continuous film of oil over them.

A cage was devised, Fig. 7, which would be definitely located and could not be displaced by more than a few thousandths of an inch by the centrifugal load. It is made in two halves, split in a plane at right angles to the axis of the bearing and spigoted together; eight hemispherical holes were made with 0.010 in. clearance for the balls; the outside circumference was turned down in a flat V to avoid the actual ball path and on either side of the V was a cylindrical surface turned dead true about 5/16 in. wide. The outside diameter of the cage was made to fit in the outer ball race which had two cylindrical surfaces ground on to it on either side of the ball path and a clearance between the cage and the cylindrical part of the outer race was 0.005 in. to 0.007 in. The material of the cage was cast phosphor bronze.

Fig. 8 shows a similar type of cage, except that it was made for a railway bearing. With this cage a radial engine was run at speeds above 1800 r.p.m. for considerable periods and no signs of wear could be detected. In general, it would seem that at speed above 1600 r.p.m. and with a radius of rotation above $2\frac{1}{2}$ in. cageless bearings will not run satisfactorily if the balls or rollers are larger than $\frac{3}{8}$ in. in diameter and the inner race larger than $\frac{1}{2}$ in. in diameter.

As regards the design of the located cage, the principal point besides making the cage of ample strength is to avoid any chance of the location of the cage being provided by the balls or rollers themselves, as this would cause the heavy abrasive loads which quickly ruin this type of bearing.

In addition to the above an appendix is attached giving some particulars of the big-end roller and ball bearings which have been found both successful and unsuccessful in practice. Also, a general method is given for finding the abrasive loads on the balls in an uncaged bearing subject to rotation about an external center.

In the case of a caged bearing a method is given whereby the

pressure load on the cage bearing surface may be found for a located cage design. A method is also given by which the total bearing load due to the cage itself and the cumulative loads from the rollers or balls may be estimated when the bearing as a whole rotates about a center without its axis.

In considering the constant comparison for the various bearings, since the wear on the bearing appears to depend almost entirely on the abrasion of the roller, an attempt has been made to find a constant for any bearing which will incorporate the factors controlling the roller abrasion.

The roller abrasion depends, it would appear from observation, on three factors: the pressure between adjacent rollers, the rubbing speed between these rollers, and the length of the line of contact. For this reason the constant K has been chosen equal to the product of the first two items divided by the last—that is: K = inter-roller pressure $\times$ inter-roller rubbing speed/length of rollers, the pressure being in lb., the rubbing speed in ft. per sec., and the roller length in inches.

From this it will be at once obvious that the ball bearing, having only point contact between the balls, is at the outset at a very great disadvantage if used without a cage.

Ball bearings should not be used for a bearing rotating about an external center unless an efficient form of located cage is provided.

From the results tabulated in the original article for the uncaged roller bearings it will be seen that for an indefinite endurance the value of K should not be more than 1000.

If the line of the bearing may be limited to about 50 hours before replacement, values of K as high as 1500 may be used; in general this value should not be exceeded.

In regard to the caged bearings, the constant of comparison K_c is equal to the rubbing speed of the cage multiplied by the bearing pressure on the cage. It will be seen that the value of K may for a bearing of indefinite life be safely more than 2500, though this figure should serve as a good guide to designers. (*The Automobile Engineer*, vol. 9, no. 128, July 1919, pp. 200-204, 10 figs., *ptA*)

MUNITIONS AND MILITARY ENGINEERING

CHARACTERISTICS OF RIFLE-BARREL STEEL. Abstract of an advance publication of two papers to be presented at the September Chicago meeting of the American Institute of Mining and Metallurgical Engineers.

One of these papers, by G. F. Butterworth, of the U. S. Armory, Springfield, Mass., deals with the Metallography of Rifle Barrel Steel; the other, on Erosion Tests of Rifle Barrels, is by A. E. Bellis, Ordnance Department, U. S. Army.

The first paper points out that the metallographic structures most frequently encountered in rifle barrels fall naturally into two groups distinguished by the method used to produce in the stock a physical condition having the requisite properties. The first group consists of rolled barrels or barrels subjected to hot-working by rolling in or near the critical range. In the second group the stock is upset to form the butt end and then heat-treated by giving it a quench and a draw. These barrels are referred to in the paper as heat-treated barrels.

The structure of the rolled barrels resembles closely that of the same steel after annealing, the grain size being closely related to the rolling temperature. Barrels rolled within the temperature range between 1300 and 1350 deg. fahr. give an exceedingly fine grain, but as the temperature is increased the grains are found to be larger. If the rolling temperature is below the critical range given above, the structure previous to rolling is not obliterated, the only effect of rolling being to elongate the coarse sorbite grains in the direction of rolling.

Heat-treated barrels are quenched in oil from above the critical range, which should give a martensitic structure, but the presence of some troostite in the martensite is frequently noted when the quench has not been sufficiently drastic. The structure brought about by the subsequent draw is sorbitic or sorbito-pearlitic. The structure is substantially the same for all drawing temperatures from 800 to 1300 deg. fahr., but the color of the specimen varies with the drawing temperature, becoming lighter as the temperature increases. Microscopic evidences of defective heat treatment are also discussed.

The paper by Maj. A. E. Bellis on Erosion Tests of Rifle Barrels calls attention to the fact that the extent to which the nature of the steel is a factor in erosion is still a much-discussed question. The paper describes tests made to determine the factor of erosion of gun barrels. The experiments performed appear to indicate that the homogeneous structure of a heat-treated barrel offers the best resistance to erosion. On the other hand, a barrel showing a network of free ferrite apparently offered easily eroded channels to the washing-out action of hot gases and metals. (*Iron Age*, vol. 104, no. 4, July 24, 1919, pp. 225-228, 23 figs., *etA*)

PHYSICS

Langmuir Postulates Regarding Structure of Matter

THE ARRANGEMENT OF ELECTRONS IN ATOMS AND MOLECULES, Irving Langmuir. Abstract of the first installment of a paper on the structure of matter. Particular attention is called to this paper, as it represents a development of possibly fundamental importance in our knowledge of atomic structure. The main assumption in this theory is that the electrons are stationary and situated in concentrated shells. By means of this theory the writer found that it is possible to explain the periodic properties of the elements and also succeeded in evolving a new view of chemical valency.

In the opinion of the author there is much chemical evidence, especially in the field of stereochemistry, that the primary balance forces between atoms act in directions nearly fixed with respect to each other. This can only be satisfactorily accounted for or explained by electrons arranged in three dimensions. There is conclusive evidence that in substances such as wood carbonized under certain conditions or finely divided WO_3 (tungsten trioxide) reduced in very dry hydrogen the atoms are arranged in branching chains in which most atoms are surrounded by only two or three others. Since the bodies are definitely solid it must follow that the atoms are not able to shift their relative positions except when acted on by strong external forces. Such structures are inconceivable if atoms contain only electrons revolving in orbits about their nuclei.

In attempting to determine the arrangement of electrons in atoms the author was guided by the numbers of electrons which make up the atoms of the inert gases; in other words, by the atomic numbers of these elements, namely, helium 2, neon 10, argon 18, krypton 36, xenon 54 and niton 86. Rydberg has pointed out that these numbers are obtained from the series

$$N = 2\ (1 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2 +)$$

The factor 2 suggests a fundamental twofold symmetry for all stable atoms. By a consideration of this factor and principles of chemistry and from other data the writer has been led to the seven postulates reproduced below.

Postulate 1 The electrons in the atoms of the inert gases are arranged about the nucleus in pairs symmetrically placed with respect to a plane passing through the nucleus which we may call the equatorial plane. The atoms are symmetrical with respect to a polar axis perpendicular to the plane and passing through the nucleus. They have also four secondary planes of symmetry passing through the polar axis and making angles of 45 deg. with each other. The symmetry thus corresponds to that of a tetragonal crystal. Since the electrons must occur in pairs symmetrical to the equational plane there are no electrons in this plane.

Postulate 2 The electrons in the atoms are distributed through a series of concentric spherical shells. All the shells in a given atom are of equal thickness. If the mean of the inner and outer radii be considered to be the effective radius of the shell then the radii of the different shells stand in the ratio 1:2:3:4, and the effective surfaces of the shells are in the ratio $1:2^2:3^2:4^2$.

Postulate 3 Each spherical shell is divided into a number of

cellular spaces each of which may contain one or two electrons. The thickness of these cells measured in a radial direction is equal to the thickness of the shell and is therefore the same (Postulate 2) for all the cells in the atom. In any given atom the cells occupy equal areas in their respective shells. All the cells in an atom have therefore equal volumes. The first postulate, regarding symmetry, applies also to the location of the cells. The first shell therefore contains two cells obtained by dividing the shell into two equal parts by the equatorial plane. The second shell having four times the surface (Postulate 2) must contain eight cells. The third shell thus contains 18 while the fourth contains 32 cells. Or if we consider only one hemisphere the numbers in the successive shells are 1, 4, 9 and 16.

Postulate 4 Each of the two innermost cells can contain only one electron but each of the other cells is capable of holding two. There can be no electrons in the outside shell until all the inner shells contain their maximum numbers of electrons. In the outside shell two electrons can occupy a single cell only when all other cells contain at least one electron. We may assume that two electrons occupying the same cell are at different distances from the nucleus. Each shell, containing its full quota of electrons, thus consists of two "layers." We will find it convenient to refer to these layers of electrons by the symbols I, II*a*, II*b*, III*a*, III*b* and IV*a*, where the Roman numerals denote the shell containing the layer. Helium, neon, argon, krypton or xenon contains respectively the first 1, 2, 3, 4 or 5 of these layers, while niton contains all six.

The two-fold symmetry assumed in Postulate 1 is derived from the factor 2 which occurs in Rydberg's equation. The fourfold symmetry is derived from the remarkable numerical relation brought out in Table 2.

TABLE 2

Shell	Radius	n	Number of cells	
			in axis	in zones
I	1	1	1	0
II	2	4	0	4
III	3	9	1	8
IV	4	16	0	16

Here n represents the number of cells in one of the hemispheres of the shell. If this number is odd one of the cells must lie along the polar axis; all other cells must be distributed in zones about this axis.

We see from this table that the number of cells which must be arranged in zones is always a multiple of four. We can therefore assume tetragonal symmetry for the atoms of the inert gases.

Postulate 5 It is assumed that electrons contained in the same cell are nearly without effect on each other. But the electrons in the outside layer tend to line themselves up (in a radial direction) with those of the underlying shell because of a magnetic field, probably always to be associated with electrons bound in atoms (Parson's magneton theory). This attraction may be more or less counteracted by the electrostatic repulsion between the outside electrons and those in the underlying shell. The electrons in the outside layer also repel each other and thus tend to distribute themselves among the available cells so as to be as far apart as possible. The actual positions of equilibrium depend on a balance between these three sets of forces, together with the attractive force exerted by the nucleus.

Postulate 6 When the number of electrons in the outside layer is small, the magnetic attraction exerted by the electrons of the inner shells tends to predominate over the electrostatic repulsion, but when the atomic number and the number of electrons in the outside layer increase, the electrostatic forces become the controlling factor. As a result, when there are few electrons in the outer layer these arrange themselves in the cells over those of the underlying shell, but where the outside layer begins to approach its full quota of electrons, the cells over the underlying electrons tend to remain empty.

Postulate 7 The properties of the atoms are determined by the number and arrangement of electrons in the outside layer, and the ease with which they are able to revert to more stable forms by giving up or taking up electrons, or by sharing their outside electrons with the atoms with which they combine. The tendencies to revert to the forms represented by the atoms of the inert gases are the strongest, but there are a few other forms of high symmetry such as those corresponding to certain possible forms of Ni, Pd, Er and Pt atoms toward which atoms have a weaker tendency to revert (by giving up electrons only).

These seven postulates are applied by the author to derive the properties of the chemical elements, thus establishing a new basis for the theory of the structure of matter. This part of the paper will be abstracted in an early issue. (*General Electric Review*, vol. 22, no. 7, July 1919, pp. 505-516, 1 fig., to be continued. The paper has also been published in the *Journal of the American Chemical Society*, vol. 41.)

RAILROAD ENGINEERING

Pennsylvania Mallet Compound Locomotives. Description of pusher Mallet locomotives of the 0-8-8-0 type built for the Pennsylvania Lines West by the Baldwin Locomotive Works.

The locomotives are designed for heavy yard service and develop a tractive force of 100,000 lb.

These locomotives embody some features of the Baldwin practice not previously used on the Pennsylvania. They have conical wagon-type boilers with radially stayed fireboxes and three rows of Baldwin expansion stays to support the front end of the crown. The arch is supported on five tubes and firing is done by means of a Duplex stoker. The throttle is equipped with an auxiliary drifting valve.

The equalization of the rear group of wheels is continuous on each side of the locomotive. In the case of the front group the springs of the leading wheels are cross-equalized, while those of the remaining three pairs of wheels are equalized together on each side. The valve gear of the Walschaerts type and the gears are controlled by the Ragonnet type B reverse mechanism. The diameter of the driving wheels is only 51 in., because of which the low-pressure cylinders are placed at an angle of 1 in 35 to provide sufficient clearance above the rails. (*Railway Review*, vol. 65, no. 5, August 2, 1919, pp. 157-159, 5 figs., *d*)

REFRIGERATION

Novel Features in Ice-Plant Design, Including Copper Steam Condensers

Ice Plant of the Colorado Ice and Cold Storage Company in Denver, Victor J. Azbe, Mem.Am.Soc.M.E. Description of a plant having some novel features of design. The plant, the full capacity of which is 350 tons of ice per day, is driven by Corliss engines which exhaust at atmospheric pressure into steam condensers. Contrary to standard practice, however, these condensers are drums 10 ft. long and 37 in. in diameter made of thin-gage copper. When the plant is operated under full capacity there are 14 of these condensers in use, which means that each unit condenses steam for 25 tons of ice each 24 hours.

It is stated that copper condensers not only give better heat conduction than iron, but are also self-cleaning. The writer describes the following demonstration made for his benefit: From a heavy-scale-coated condenser steam was shut off but cooling water allowed to circulate. Immediately the scale began to crack and fall off and expose the clean, smooth copper surface. In this way most of the scale came off and after a few minutes the water was turned off and the steam on. This dried the surface

and by tapping slightly with a wooden mallet the remaining scale was removed. The whole operation of cleaning did not require much over five minutes. Another advantage of this type of condenser is that it is more durable and eventually easily repaired.

The freezing system is of the can type, freezing 800-lb. ice blocks, which it does very successfully. The cans proper are $23\frac{1}{2}$ in. by $12\frac{1}{2}$ in. at the top, $22\frac{1}{2}$ in. by 12 in. at the bottom and 7 ft. 11 in. long. As far as the effort of pulling is concerned, there is stated to be less of it here than is usually encountered with cans of half the size, which is, however, due to the type of electric crane that is employed.

Ammonia refrigeration is used. The ammonia condensing system consists of 29 spans of drip condensers, all being 24 pipes high and 20 ft. long. In addition, the plant is equipped with

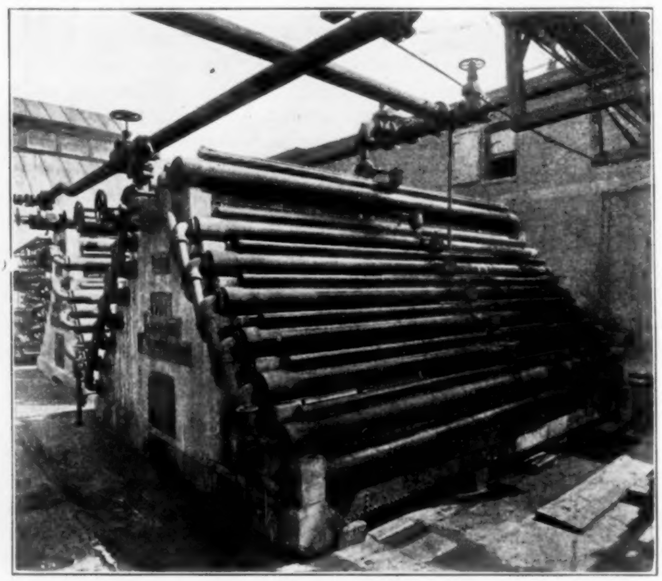

Fig. 9 Vail Ammonia Condenser

condensers designed by George L. Vail, chief engineer of the company, made up of 8-in. standard pipes and arranged as shown in Fig. 9.

Ammonia vapor flows successively through 14 lengths of 8-in. pipe, each having 18 ft. of effective length. The 8-in. pipes are interconnected by 2-in. pipes. While the velocity in this condenser is relatively low, the results obtained are said to be good.

The ice-storage house is 175 ft. long, 60 ft. wide and as much as 60 ft. high, which means that there are 30 layers and 500 tons of ice to the layer. At first objections were offered to building an ice-storage house of such a height as it was thought that the lower layers would not sustain the weight, but tests with an ice block under a hydraulic press showed that such fears were groundless. (*Power*, vol. 50, no. 5, July 29, 1919, pp. 168-170, 6 figs., *d*)

Just How Much Do We Know About Carbon Dioxide?

The Design of CO_2 Machines, John E. Starr, Mem.Am.Soc. M.E. The author points out that while the design of ammonia machines has advanced to a rather fine point and the knowledge of the behavior of ammonia is nearly perfect, the same does not apply to the case of machines employing other fluids, especially carbon dioxide. Machines of this class are often made either too large or too small for their intended duty and tables on the properties of carbon dioxide give results varying to such an extent as to produce at times as much as 50 or 60 per cent variation in the design of the engine.

For example, the curves in Fig. 10 compare the results of the heat content of liquid CO_2 in Siebel's Compendium of Mechanical Refrigeration and Engineering and in Le Doux' Ice-Making Machines with the work credited to Mollier and Amagat.

At first glance the last three sets of the curves do not appear to present discrepancies which would lead to a very great difference in ultimate design of the machines, but in a fluid such as CO_2 where the heat of liquid constitutes so great a proportion of the heat of vaporization, the actual variation greatly affects the results.

The following calculation reproduced from the original article is of considerable interest:

Taking the two principal tabulations and assuming 0 deg. fahr.

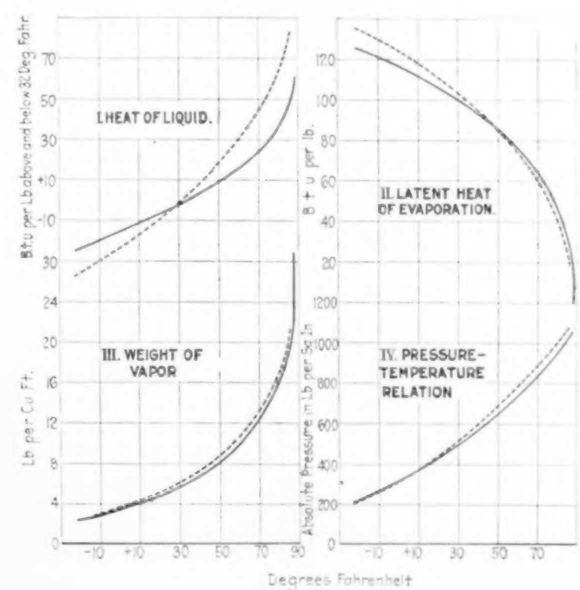

Fig. 10 Properties of Carbon Dioxide as Given by Different Authorities

(Broken Lines—Data given by Professor Schroeter in Le Doux's Book; Full Lines—More recent observations credited to Amagat and Mollier by Macintire.)

for the refrigerating temperature, and 80 deg. fahr. for the average temperature at which heat is rejected in the condenser the designer at once finds himself in a quandary. From the older set of tables (Schroeter, page 174 of Le Doux's book, 1902) he finds the following values:

Heat of vaporization at 0 fahr........	125.5 B.t.u.
Heat of liquid at 0 deg..............	—24 B.t.u.
Heat of liquid at 80 deg..............	+63 B.t.u.

Hence, net heat taken up per lb. $= 125.5 - (-24 + 63) = 38.5$ B.t.u. Therefore, 200 B.t.u. per min. (= 1 ton of refrigeration) $\div 38.5 = 5.2$ lb. of CO_2 required per ton. He further finds the weight of a cubic foot of gas to be 3.45 lb., or 0.2898 cu. ft. for 1 lb., or total for the necessary 5.2 lb. $= 5.2 \times 0.2898 =$ *1.506 cu. ft.* to be compressed per ton from 310 lb. up to 990 lb. absolute pressure.

From the newer tables (prepared by Mollier) he finds:

Heat of vaporization at 0 deg. fahr....	117 B.t.u.
Heat of liquid at 0 deg. fahr..........	—17 B.t.u.
Heat of liquid at 80 deg. fahr.........	+36 B.t.u.

Hence, net heat abstracted per pound $= 117 - (-17 + 36) =$ 64 B.t.u., and $200/64 = 3.12$ lb. CO_2 to be circulated per minute per ton of refrigeration. Weight of vapor per cubic foot = 3.45 lb., and $1/3.45 = 0.2898$ cu. ft. per lb. Therefore 3.12×0.2898 = *0.9041 cu. ft.* of vapor to be compressed per minute per ton from 310 to 965 lb. absolute pressure.

This is a difference of $66\frac{1}{2}$ per cent in the size of the machine, and as there is very little difference shown in pressures, the economy will also vary about $66\frac{1}{2}$ per cent!

The writer suggests that the Bureau of Standards is the proper authority to settle this matter. (*Refrigerating World*, vol. 54, no. 7, July 1919, pp. 11 to 12 and 20, 1 fig., *t*)

STEAM ENGINEERING

Drop Valves for Steam Engines. Discussion and criticism of the usual Cornish double-beat valve, especially as applied to engines working with superheated steam, and of the Lentz gear.

The author proposes to use instead the valve shown in Fig. 11,

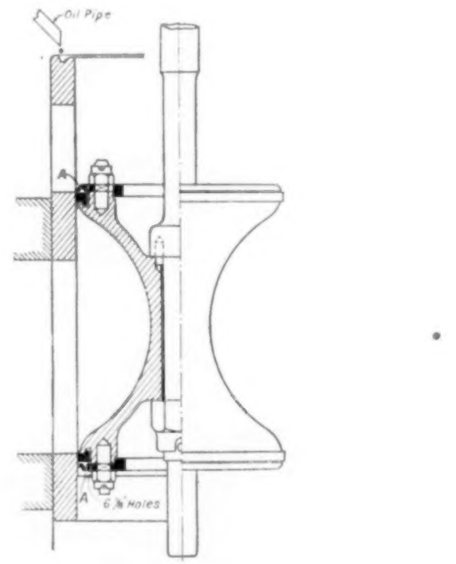

Fig. 11 Piston-Type Drop Valve for Steam Engines

only, however, as a steam-admission valve, and states that such a valve has been used in one instance for seven years and has shown practically no wear.

The valve works in a separate liner forced into the cylinder, the seatings being machined and, if necessary, scraped, so as to be circular when cold. The result of pressing the liner in is that where it touches the cylinder it is contracted. Hence, where the rings seat the bore of the liner becomes less than on either side of that seating. If the ports be cast in, the liner has a tendency to crack, and they are therefore cut from the solid. Now, the rings are restrained by a return flange on the faces. In the steam valve shown they are on the inner faces, but in the exhaust valves they are on the opposite faces. On those faces between the restraining flange and the liner, the rings are a ground fit to the valve, hence steamtight. The ring is not a tight fit in the grooves, but is kept up to its face by a wave spring in the recess *A* shown. Further, the rings are steam-packed, in the case of the inlet valve, by the incoming steam, and of the exhaust valve by the cylinder steam, or from the side on which there is the greatest pressure. The points in the rings are not lapped, but usually just radial, and the joint is pegged opposite one of the grids in the liner. The valve body is clear of the liner, and does not touch in work. It is pegged so that it cannot turn on the spindle, and all is so arranged that once set the valve commences and ends its life without circular movement. But it is necessary that the gland should not prevent the spindle from making slight movements at right angles to the axis of the liner. In work, then, the cylinder will distort the valve liner more in some designs of cylinders than others, but the rings being flexible to the necessary slight amount, follow at the first irregularities and later wear to them. At first sight the restraining flange may appear to prevent this automatic adjustment, and it was at first only used to prevent parts of the rings getting into the ports in case of breakage; but piston rings in work, whether in the piston or valve, expand more than the cylinder or liner—at least, all the writer's experiments have proved this—and, again, the rings are made a fit to the liner before it is forced in. Hence, when the valve is on the seating part of the liner, the rings are off their restraint. With care, then, these valves can be maintained reasonably steamtight. (*The Engineer*, vol. 128, no. 3315, July 11, 1919, pp. 25-26, 4 figs. *d*)

THERMODYNAMICS (See Refrigeration)

VARIA

Absolute Measurement of the Intensity of Sound, Prof. A. G. Webster. Description of a series of acoustical researches dealing, among other things, with the properties of vibrating bodies and the subject of elastic hysteresis.

An instrument has been developed called, the "phone," which is a standard of sound and is capable of reproducing at any time a sound of the simplest character and permits measuring the output of sound in watts of energy.

A second instrument has been developed for measuring the sound in absolute measure. This instrument, called a "phonometer," is now practically as sensitive as the human ear.

By means of these instruments the determination of the space distribution of sound, of the effect of disturbing bodies and measurement of the reflecting coefficient of surfaces have been accomplished.

In the same paper is briefly described an instrument called a "phonotrope," the purpose of which is to find the direction of location of a source of sound—for example, a false signal. Owing to the Doppler effect it cannot yet be used to determine the direction of an aeroplane at night. (*Proceedings of the American Institute of Electrical Engineers*, vol. 38, no. 7, July 1919, pp. 889-900, 7 figs., *dA*)

Dazzle Painting of Ships, Lt.-Comm. Norman Wilkinson, R. N. V. R. Dazzle painting is defined as a method to produce, by paint, an effect in such a way that all accepted forms of a ship are broken up by masses of strangely contrasted colors. The purpose of it is to make it difficult for a submarine to decide on the exact course of the vessel to be attacked.

Invisibility against submarines is not only impossible but said to be dangerous, and marine camouflage is in this respect radically different from sea camouflage. The primary object of the camouflaged vessel was not so much to cause the enemy to miss its shot when actually in firing position (although this has happened in a number of cases) but to mislead him when the ship was first sighted as to the correct position to take up. With a vessel of 10 knots or over a submarine having once failed to obtain a good position has little or no likelihood of regaining that position owing to insufficient underwater speed.

Should the submarine decide to come up the ship attacked, being armed, has every chance of a successful escape, and, in fact, the coming out of the submarine would in itself be a good testimony to the success of the painting.

The striped type of dazzle design which was most successful was arrived at some time before the end of the war. In the initial stages a small wooden model of each ship was made to scale. On this a design was painted in wash colors and the model was carefully studied on a prepared theater through a submarine periscope, various sky backgrounds being placed behind her alternately. A satisfactory design having been evolved giving the maximum distortion, the model was then handed to a trained plan-maker and copied.

The most important parts of a ship on which distortion should be obtained are in the neighborhood of the stem and the forebridge, both of these being of great use to a submarine in determining the course. The colors mostly in use were black, white, blue and green, either in their primary condition or mixed to various tones. The speed developed in dazzle painting was such that, for example, the Leviathan was marked out in just over two days. (Paper read before the Northeast Coast Institution of Engineers and Shipbuilders, July 10, 1919. Compare *Engineering*, vol. 108, no. 2797, August 8, 1919, pp. 192-195, 5 figs., *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

MECHANICAL ENGINEERING
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Engineering Societies Employment Bureau

The work of the Engineering Societies Employment Bureau has increased rather than decreased during the summer months. Engineers just being released from Government service continue in as great numbers as during last spring to seek employment through the agency of the Bureau. Employers, realizing the good material which may be secured by means of the Bureau, are increasing their demands upon it. In addition to the calls for engineers there are many requests for designers, draftsmen, and minor assistants. Statistics of the work of the Bureau for the eight months ending July 31 last are as follows:

Applications for employment	3763
Positions registered	1334
Positions open at present	350
Applicants placed to date	744
Average number of men visiting Bureau per month	1690
Average number of men sent out for interview per month	675
Average number of letters of application for positions forwarded per month	1457

There is every reason, however, to believe that many more than 744 applicants have been placed who have failed to notify the Bureau.

Recataloging the Engineering Societies Library

Attention is called to the interesting report in another column by Director Harrison W. Craver of the library in the Engineering Societies Building, New York, on the subject of library cataloging and the classification of engineering literature. This great library originally comprised the books of the libraries of the Mining, Mechanical and Electrical Engineers, to which later was added the large and very complete collection of the Civil Engineers. Each originally had its own library catalog, from which, as explained by Mr. Craver, a general authors' catalog was made by interfiling the catalogs of the constituent libraries. There is also an alphabetical classified catalog of the three original collections, a classified subject catalog of the Civil Engineers, and other catalogs and lists.

Work of recataloging is now under way, a very large undertaking which will require from two to three years to complete. There will be an authors' catalog to enable the reader to find a book when the name of an author is known, or what books by any author are in the library; a subject catalog to enable the reader to find a book when the subject is known, and to exhibit the resources of the library on every chief and most subordinate topics; and an alphabetical index which will comprise the names of the various subjects upon which there are important books or pamphlets and which will direct the user to that section of the subject catalog where the books are listed and to the department of the library where they are to be found.

The Dewey system of classification will be used as extended and modified by the Institut International de Bibliographie, usually known as the "Brussels" classification.

The principles underlying this work are explained in the report as well as the details of the system of classification used. The report should prove of value to engineers generally, apart from its direct bearing on the work now in hand for the library of the Engineering Societies.

The Training of Industrial Executives

The successful conduct of manufacturing enterprises demands that type of managerial talent which fully comprehends and effectively coördinates the social, commercial and technical forces which condition the life and prosperity of such institutions. The proper embodiment of physical, chemical and mechanical laws in industrial processes is the first essential in establishing a manufacturing enterprise upon a good technical foundation.

The provision of those conditions which release the creative faculties of the mind, which bring about the coöperative efforts of men and which establish understanding between labor and capital, are the golden fruits of management.

The distribution and marketing of the products of the factory, the financing of the enterprise and control of its activities in the light of market conditions are among the most serious problems dealt with in directing the affairs of an industrial undertaking. Accordingly, therefore, any training for service in manufacturing and industry which has for its object the development of men who shall occupy executive positions should be directed toward the great problems of labor and the human side of engineering, the problems of costs, accounting and finance, as well as the scientific and technical problems arising in industrial processes.

We are beginning to realize that the management of industrial enterprises is a matter of public interest and concern. The late war has demonstrated most forcefully the fact that our ability to combat is in direct proportion to our ability to produce goods; and between nations of equal resources the decision is generally in favor of the one which can produce, handle and use its goods most economically. As we enter the reconstruction period and begin to adjust ourselves to the new economic and social conditions which have arisen as a consequence of the war, we realize as never before that one of our greatest natural problems is the economic production and distribution of goods. And the greatest factor in this problem is that of man power or executive ability. We do not lack devices for production, systems of credit, methods of management—the tools to work with—but our need is men of vision, ability and force, well trained in commerce, finance and technology to direct our industrial organizations and cause them to function properly in all these particulars.

The development of men for such service is important to the public welfare. It is of more than passing interest, therefore, to note that the Engineering Schools of Columbia University have given serious consideration to this question and have developed a plan for training men for this service. Some years past Columbia, appreciating the growing importance of all engineering service to the public welfare and the increasing responsibility of the engineer to the public, raised its requirements for attainment of its engineering degrees to provide a more liberal education in the arts and the humanities. It is provided that this new development shall also stand on the same broad educational foundation. An equivalent of three years' college training will therefore be required of all candidates for instruction in this branch of service.

The instruction under the supervision of the engineering faculty extends over a period of three years, and is about equally divided between technical and commercial subjects. The School of Business of Columbia University is coöperating in the project and will give instruction in commercial practice and finance.

At a recent meeting of business men and educators held in Washington it developed that the Carnegie Institute of Technology and the University of Cincinnati were also working out similar projects and were offering instruction at the present time in those commercial subjects which are most important in matters dealing with the management of factories and the conduct of commercial enterprise.

With our universities and colleges developing men of broad vision and understanding in matters relating to the industrial and commercial development of our country, and with the introduction of these men into our business life, it is felt that the whole plane of commercial operation will be lifted and the problems perplexing labor and capital will be more thoroughly understood and more wisely handled.

Walter Rautenstrauch.

Aeroplane Fuels

About the time when the United States entered into the war the air was full of rumors of wonderful German achievements in the field of heavier-than-air flying. The usefulness of the zeppelin as an engine of warfare was pretty well discredited, but it was said that the Germans had some wonderful invisible aeroplanes, armored aeroplanes, etc. One particularly persistent and disquieting rumor was that the Germans had developed mass production of a new fuel belonging to the class of hydrogenated benzols and known as cyclohexane.

An extensive research undertaken by the Bureau of Mines, together with other governmental and private agencies, had for its purpose (1) to determine the conditions surrounding the combustion of fuels in aeroplane engines of varying ratios of compression, and (2) to develop the production of synthetic fuels of the hydrogenated-benzol type.

Highly gratifying results were secured in both lines of this research, even though neither was developed in time to be of practical use before the signing of the armistice in November of last year.

In the first place, it was found that the various fuels behaved in a definite manner under various degrees of compression. It was found that a fuel could actually be "crushed" under the compression so that it would ignite spontaneously. It appears that of the commercially known fuels kerosene has a comparatively low upper limit of usage in high-compression engines; gasoline comes next; following which come the various compound and synthetic fuels.

It was further determined that under a compression ratio of 8.221, corresponding to a pressure of 185 lb. per sq. in. as measured with an Edelman gage, cyclohexane-benzol alcohol and alcohol-benzol-gasoline mixtures showed only a slight tendency to cause knocking, which, when it occurs, may mean either preignition or excessively rapid combustion.

A mixture composed of 70 to 80 per cent cyclohexane and 20 to 30 per cent benzol, called "hecter," was developed and rapid strides were being made in volume production of cyclohexane when the armistice put an end to this kind of work so far as the Government was concerned.

The immense value of research of this nature is obvious to any engineer and it can only be regretted that the pressure of the terrible war emergency was apparently needed to attract sufficient interest and secure adequate means for work of the character indicated.

Corrosion of Non-Ferrous Metals and Alloys

In the Engineering Survey of this number will be found abstracts of two papers presented before the American Institute of Mining and Metallurgical Engineers on the general subject of corrosion of non-ferrous metals and alloys. These report valuable work done at the U. S. Bureau of Standards and point to a new and promising field of research concerning the behavior of our basic materials of engineering construction.

When the average man speaks of corrosion of metals he has primarily in mind the corrosion of the universal metal, steel, which unfortunately is so subject to the action of the elements. The general assumption is that non-ferrous metals, in particular those with a copper base, are fairly free from corrosion. Because of this, copper, brass and bronze are used in places where the element of construction is particularly subject to corrosion and, as a rule, it is assumed that the yellow metal or alloy will insure practically complete protection from corrosion.

The work done by the Bureau of Standards, however, shows that this is not always the case and that not only aluminum alloys, which it is well known are subject to corrosive action, but under certain conditions brass and bronze suffer from corrosion to an extent sufficient to impair their usefulness as structural materials.

In particular, the paper by P. D. Merica and R. W. Woodward indicates that brass and bronze may be subject to failure when under tensile stress greater than 20,000 lb. per sq. in. and at the same time under corrosive action such as results, for example, from concentrated ammonium hydroxide.

The value of this investigation lies in its contribution toward a clearer knowledge of the life and factors of safety of basic materials of engineering construction and if carried further may indicate the need for more stringent rules for the employment of these factors in places where the metal is subject to hitherto little-suspected destructive agencies.

Ball and Roller Bearings Under Centrifugal Loads

The development of aeronautical engines had made it necessary to use somewhat unusual combinations of machine elements or to employ known elements under new and unusual conditions of operation. One such case was that of a ball and roller bearing rotating as a whole about an axis external to its own geometric center. It was found that if the rollers or balls were above a certain size and the speed of rotation high, bearings with cages of the ordinary type, and bearings without cages, had a very short life.

A series of tests and investigations have been undertaken by the Technical Department, British Aircraft Production, which show that in such cases we have to deal with piling up of the balls or rollers due to the action of centrifugal forces. This in its turn led not only to the development of a new type of bearing, but also to the evolution of the theory of "located" cage design and special uncaged roller bearings. This matter is covered in the abstract of a report of the investigation published in the Engineering Survey section of this number.

The National Budget

A National Budget System is favored by both the republican and democratic parties, and a resolution has been adopted in both Houses, whereby select committees on the budget system have been appointed consisting of 10 members on the Senate Committee and 12 members on House Committee. To these committees will be referred all reports on bills, resolutions and documents for the establishment of a National Budget System, as well as proposed changes in dealing with appropriations, estimates and expenditures.

An outline of the budget plans for our own Government and the budget system used in foreign countries has been submitted, together with an outline of the essentials of the budget system and anticipated results. The Senate Committee, of which Senator McCormick of Illinois is chairman, is now framing and will later present proposed legislation for a Budget System on or before March 1, 1920.

AFTER-WAR EUROPEAN INDUSTRIAL ACTIVITY

Early in March 1919 a large delegation of the Cleveland Chamber of Commerce went to Europe to study industrial conditions for the benefit of their community. Mr. E. S. Carman, the former chairman of the Cleveland Section of The American Society of Mechanical Engineers, and the president of the Cleveland Engineering Society, was a member of the delegation and since returning has delivered a number of addresses giving in a general way the results of his observations on after-war European industrial activity. In these he has told his audiences most interestingly his impressions of the trade conditions in the several countries of the Allies and of the destruction wrought in Belgium. In what follows are given excerpts from his remarks that we believe will be equally as interesting to the larger audience comprised by the members of this Society and the other readers of MECHANICAL ENGINEERING. In these addresses Mr. Carman was said in part:

"I have had the great privilege of visiting England, France and Italy and Belgium's industrial plants and of coming in personal contact with their managing directors and engineers and have seen and heard first hand just the condition existing in the various countries from four to six months after the signing of the armistice.

"Arriving in England in early March, I spent two weeks studying the Englishman at home. I heard his complaint, his grumble, his expressed dissatisfaction with his government, with labor, with railroads, with the weather, in fact with everything and everybody—even Americans. His home was cold, exchange value of sterling made the American dollar standard, his food was poor and portions small; he did not have butter, sugar, or cream and he feared that which he did have President Wilson was going to give to the Huns. There was not much activity industrially and labor as a whole threatened to strike on Sunday morning, March 23. The arrogant demands of labor was the paramount talk of the day. The Englishman needed the holiday he had not had for five long years.

"In France the people seemed to be enjoying their new-found and unexpected freedom from the bitter fighting of the past five years. They seemed happy, content and ambitious to take up again the life of peace and happiness. In Paris one is surprised at the gaiety of the throng.

"After visiting the northwest battlefields I left France for a time, entering Belgium. It was here that one asked the question, 'Can Belgium ever regain the industrial position she once held? Can she be a factor in the competition for the export trade of the world?'

"Her industrial plants, stripped by the Hun, are as skeletons, standing upright in all their ghastly nakedness; their hearts have ceased to beat, their flesh, yea, their souls have disappeared, and through their broken windows there shines a light to show the occasional visitor the heartlessness of the Hun.

"We have heard and read of the wilful destruction of the cities and industrial plants of Belgium and Northern France, but neither words nor pen can adequately convey to the mind the real conception of what the eyes can see and the heart can feel—for one must see with his own eyes and hear with his own ears, before he can conceive of the completeness of the devastation that was wrought.

"Then, too, one sees there the human side of after-war, and, if at all sympathetic, his heart is deeply touched.

"I called on a former customer of ours at his office-home in Brussels; a builder of large engines, both steam and gas, also general engineering work. I was shown into the office of the owner(a man of about 55 years of age) and there—after I had convinced him that I was not trying to sell him something but just sympathetically inquiring what I could do to help—he told me the story of his misfortune.

"It developed that his plant was equipped thoroughly with machines of English, Belgian, American and Dutch manufacture. He further stated that of all this large equipment the only thing left was that which was made in Holland as the equipment manufactured in England, Belgium and America had been carried away into Germany.

"It was a sad situation indeed and one that pulled severely at the heart strings to sit in conversation with one who, like the owner of this works, had been well-to-do practically all his life and now, at the age of about 55, did not have a single thing left, and the only people in this large establishment were about six people in the outer office in Brussels.

"In a discussion as to how this vast amount of equipment would be replaced, he admitted he could not see how it could be purchased from America or England, and in answer to the question as to whether or not Belgium could manufacture it, he replied that it could not as they have nothing to manufacture it with. The only course left open for him will be to purchase his machinery and the question is where will he purchase it. Now let us consider this problem from his standpoint. He thinks in terms of francs; they are his standard by which he gages the cost of anything, just as the dollar is ours. The franc is at a discount in dealing both with England and with America. If we quote \$1000 on a piece of machinery, this would normally be approximately 5000 francs, but now with the depreciated value of the franc, he would have to pay 7500 francs for what would still appear to him to be 5000 francs worth of machinery. The same thing is true of English quotations, but on the other hand, consider German quotations. They quote him in marks and a piece of machinery valued at \$1000 will be quoted by a German concern at approximately 4000 marks. Normally 4000 marks would mean practically a price of 8000 francs, but now with the depreciated value of the mark, a quotation of 4000 marks means only 2000 francs, so that if this Belgian manufacturer receives quotations from both America and Germany on a piece of machinery, the normal value of which is \$1000, he will receive a quotation of 7500 francs for the American machinery and only 2000 francs or less than one-third for the German machinery. With money normal, his hatred of the Hun would undoubtedly cause him to purchase the equipment here, but being poverty-stricken, as every Belgian is today, the money consideration becomes one of paramount importance. This is the great question before American manufacturers today. We have the desire to help our Allies, but can we meet conditions in such a way that it will be possible for us to do so?

"The sentiment of the large portion of the Belgian population is very much in favor of America. This was noticeable at every village and city which I visited and I especially call to mind visiting the city of Dinant with its great fortress—the city on which was based the last hopes of Belgium withstanding the German invasion of five years ago; the city that was laid low not by shell fire but by wilful destruction—it was after visiting this city and being entertained by the burgomaster and others, that, in leaving in our automobile and swinging from their main thoroughfare across the River Meuse, a large crowd of school children, waiving their handkerchiefs, cried, 'Vive L' Amerique.'

"Regarding the labor conditions in Belgium, while there was not much being said, nevertheless, upon inquiry, it was found that the workman did not care to work and that where an attempt was made to stir him to industrial activity strike after strike occurred. In many places the demands were immediately granted and then before the workers would accept that which they were striking for, they would immediately ask for more and continue the strike.

"In the city of Alost, the headquarters of the American Food Relief which has now been taken over by the Belgian Government as their headquarters, I found the squares of the city crowded with idle workmen and upon inquiry learned that men out of work were receiving 27 francs per week and with this money, which was paid by the government, they purchased their supplies cheaply from the Belgian Food Relief Stations and lived on this all week. There were at that time about 150,000 Belgians drawing this 'idle' pay.

"In contrast with this idleness it is quite evident that the farms

surrounding the cities required the help of every available man and especially so since all their horses and oxen have been killed or taken away from them by the Huns. One of the most pitiful sights which I saw was two men harnessed together drawing a heavy drag or harrow across the spaded ground.

"Italy has been a consuming nation, importing large quantities of food, clothing materials, and nearly all her iron and steel products of consumption; she has never been known as an industrial or manufacturing nation, but it is my understanding that her after-war aspiration is to become a producer instead of a consumer.

"She feels that the mechanical experience gained in war time should enable her to manufacture and so she has continued and is producing several types of machine tools, hydroelectric power units, motors, etc., as a whole they are crude looking in design and poorly built.

"It was my good fortune to visit many plants in all her large cities, excepting Venice, also a few of the Royal Navy yards and arsenals, including the largest; it was at this plant that I was shown the foundries, machine, pattern, boiler, plate and electric-welding shops. These shops were furnished with only an average equipment and that did not seem to be producing an average output. This being the largest and best navy yard, I was beginning to wonder what the others would look like, when, much to my surprise, upon arriving at the ship yard and entering an enclosure, there lay before me on the ways, a submarine just about ready for launching; it was the last of an order of six; about 20 ft. in diameter and 200 ft. long.

"We give the Italian credit for being an artist and rightly so, but when we think of art we think of painting and sculpture, of palaces and song, but hardly do we expect to see such graceful lines and curves upon a submarine, an engine of destruction. As I looked upon this thing of elegance and beauty, an artistic design with workmanship most skillful in the bending, shaping and riveting of the heavy plates, the American instinct began inquiring within, Was not this built for fighting? Was not this built to win a war, and at a time when labor, capital and skill was in great demand? Why, pray tell me, why the utter waste of labor, capital and skill necessary to fashion these heavy plates in such an artistic manner? Would not a more simple design accomplish the same work?

"What position will Italy hold in the after-war struggle for commercial supremacy? Can she put into articles for general world-wide consumption all the laborious skill that she now puts in her works of art? And can she put into her products that exceptional amount of labor which she puts in the construction of her public works? For I recall that while passing in a train I observed that a winding river in the bottom of a valley was being straightened; the cut being perhaps a mile long and the section which was being excavated was approximately 50 ft. wide by 8 ft. deep; and all this vast amount of earth was being removed by spade and wheelbarrow methods.

"As one travels throughout Italy it becomes at once apparent that the business and home life of the Italians is one of ease and primitive in manner and habits; there are not to be found the many conveniences, and in fact the necessities of the American home and office; mechanical appliances in everyday life are unknown. Labor is plentiful and cheap. Yet when output and cost are compared with ours, their costs will doubtless be much higher.

"Before Italy can export she must consume, and to teach her people to consume requires the changing of customs as old as history itself—a great task indeed.

"In France the conditions are quite different. France has a people whose habits are advanced and her workmen know how to produce a day's work for a day's pay. There seems to be a willingness on the part of the workmen.

"It was my privilege to be the first American civilian to inspect the greatly enlarged works of Schneider & Co., at Le Creusot. I have heard this company spoken of as "The Krupps of France" and so it is, for on every hand was to be seen ordnance of all sizes and description.

"This great plant which was responsible for the furnishing of much of France's war weapons, is now at work building instruments of peace and the preparation is now being made to convert still more of its many shops to the manufacture of useful peace time machinery.

"France is busily at work now, but France has years of work ahead to rebuild, repair and reëstablish her industries and that too with over three million of her best and most skillful workers either dead or disabled. Can France give attention to world-wide trade? Not yet,

"And now, what about England? Yes, England has all that is necessary in the way of equipment to have and to hold the world's trade, but one thing she lacks—a willing labor. England's labor will not work, regardless of the rate of pay; the day's output is restricted and retarded.

"Her plants are not busy. Her labor is unemployed. Her masters are indifferent and I fear in many instances unconscious of the storm that will sooner or later break in great fury. We must look further back than the near past before we can begin to suggest the causes for all this present unrest. Europe's age-old curse—man and master, snobbery and hatred—is at the bottom of all her troubles. She does not and will not recognize that all men have an inalienable right to earn a livelihood and pursue the paths of peaceful, honest and happy living. Many of the masters of industry are autocratic, as are also the masters of labor. They are continually striving one with the other.

"Can England be a factor in the race for world-wide commercial supremacy? The question is a hard one to answer and I believe from observation we shall have plenty of time to wait for a reply. England has troubles of her own."

Business Engineering at Stevens

In another column, Prof. Walter Rautenstrauch of Columbia University comments upon the movement in several colleges, including Columbia, toward courses in administrative work in combination with engineering training to prepare young men for broader activities of engineering and manufacturing. In this connection attention should be called also to the fact that in certain institutions lectures are given in business administration and economics as a part of the regular course of engineering, in distinction from the new courses referred to by Professor Rautenstrauch in which business administration is coördinate with the engineering subjects.

A pioneer in adopting such instruction is Stevens Institute of Technology. Dr. Alex. C. Humphreys, President of the Institute and Past-President of The American Society of Mechanical Engineers, combined with H. de B. Parsons in suggesting that as far as time would permit, instruction should be given at least to members of the senior class on commercial conditions and methods affecting engineering enterprises. The result of these suggestions was that a course of four lectures was delivered to the senior class in the spring of 1897, the first being prepared by Dr. Humphreys and the second by Mr. Parsons. Additional lectures were prepared by George R. Turnbull, vice-president of the Guaranty Trust Company of New York, on Accounts and Accounting, and by William Sherrer, manager of the New York Clearing House, on the Relation of Money and Banking to Engineering Work. During the next college year it was not found practicable to provide regular instruction along the lines suggested, but a brief course in accountancy was offered to the senior class in the spring of 1899.

When Dr. Humphreys assumed the presidency of Stevens Institute, he promptly determined to enlarge the scope of this instruction and, as a result, the Department of Business Engineering was established under his direct supervision; the title of the department being later changed to "Economics of Engineering."

Other lectures have been given from time to time and a selection of these have been gathered together in book form as lecture notes for the use of students. These now comprise a volume of nearly 600 pages upon such subjects as accountancy, depreciation, shop costs, analysis of data, specifications, estimates, law of contracts, patent law, and business methods in general. These probably constitute the most complete volume which has been published on what Dr. Humphreys is pleased to call The Economics of Engineering for the use of engineering students.

FORMULATION OF POWER TEST CODES

Methods of Testing Power-Plant Apparatus now being Standardized by the Largest Committee of Mechanical Engineers

TEN years ago a committee was appointed by The American Society of Mechanical Engineers, known as the Committee on Power Tests, to revise the various testing codes of the Society pertaining to boilers, pumping engines, locomotives, steam engines, internal-combustion engines, etc., and to extend these codes to include other apparatus. The report was presented at the Annual Meeting in 1915 and has since been in extensive use throughout the country.

Appreciation of the Code by the profession led to a proposal for its thorough revision, including the amplification of its several sections where necessary and the formulation of new codes to cover other types of power-plant apparatus. Accordingly, in December 1918 a committee was appointed by the Council to revise and extend the Power Test Code. Nineteen individual committees of specialists in different fields were also appointed, as listed in what follows. The following instructions and directions defining the work of these individual committees in order to facilitate coöperation and avoid conflict have been issued by the committee:

Plan of Organization

The Main Committee has charge of the plan and scope of the work, determines what codes shall be formulated, nominates or suggests those to be appointed by the Council as members of the committees charged with the formulation of the individual codes and suggests revisions if necessary to correlate their work with that of the other committees and with the general plan. When a code submitted by an individual committee is complete and satisfactory, the Main Committee transmits it to the Council with its recommendations, and when approved by the Council it is published as the A. S. M. E. Code upon its particular subject over the signatures of the members of the Individual Committee that formulated it.

The Main Committee holds stated meetings on the first Monday preceding the first Tuesday in March, June, October and December to consider reports from the Individual Committees and such other business as may properly come before it. An Executive Committee of nine of its members, easily accessible to headquarters, functions in the interim. A secretary is assigned to the committee by the Society.

Committees on Individual Codes

The policy of the Main Committee has been to select committees to formulate the individual codes with a view to obtaining the best thought and experience of the profession with regard to the special subjects in hand. The choice of members has not been confined to men belonging to the Society. Special knowledge of the subject is considered more important than society affiliation. A list of the committees, with their personnel as determined to date, is given below.

The committees are favored by the coöperation of other societies. The Committee on Hydraulic Power Plants is composed, for instance, of three representatives each from the American Society of Civil Engineers, the American Institute of Electrical Engineers, the National Electric Light Association, and our own Society. Our Committee on Refrigerating Machines and Plants is identical in its membership with the committees appointed for a similar purpose by the American Society of Refrigerating Engineers. The Mechanical Section of the American Railroad Association has officially designated Mr. A. W. Gibbs to represent that body on our Committee on Locomotives, and our Individual Committees include representatives from the U. S. Bureau of Standards, the U. S. Naval Academy Testing Station, the Machinery Builders' Society, the Hydraulic Society, etc.

The Individual Committees are expected to choose their own officers and perfect their own organization. They are free to seek the coöperation of everybody having information upon or interest in their respective subjects, especially those whose interests will be affected by the Codes. The Committee on Steam Engines, for example, wrote to 119 engine builders, telling them that the Steam Engine Code was to be revised and soliciting their suggestions and interest. Committees may avail themselves of the coöperation of other societies or committees interested in their subjects; but if it is desired to add to their membership or to invite an organization to formal participation in their work by the appointment of representatives upon their committee, recommendations should be made to the Main Committee that the persons desired be appointed or an invitation for such representation be extended by the Council.

Records of the meetings of Individual Committees are to be sent in duplicate to the Secretary of the Main Committee, in whose office one set will be kept intact for reference, the other set being available for circulation among other committees that may ask to see it.

General Instructions

The work of some of the committees is so interrelated that an interchange of records of conclusions reached or important points under consideration will be helpful if not necessary.

The chairman or secretaries of Individual Committees are to indicate to the Secretary of the Main Committee what other committees are likely to be interested in their reports and in the reports of what committees they are likely to be interested. Differences of opinion as between committees will be reconciled if possible by correspondence or joint meetings, but if irreconcilable will be reported to the Main Committee.

Description of instruments, apparatus and methods—such as the salt or color method for measuring the rate of flow of water—and their correction, calibration and use will be treated by a special committee.

Instructions which are not special to their particular codes will be referred by Individual Committees to Committee No. 1 on General Instructions.

Individual Committees will refer the definitions of terms and the fixing of values of physical constants, etc., to Committee No. 2 on Definitions and Values.

The codes formulated by the Individual Committees will treat of special applications of such instruments to their particular code; but refer to the section on Instruments and Apparatus for directions for the calibration, correction and utilization of the instruments themselves. Matter in the codes under revision or suggestions as to points desired to be included in the treatment of instruments, apparatus or methods involved in their work, or already completed upon such instruments applicable to other codes, are to be referred by Individual Committees to Committee No. 19 on Instruments and Apparatus.

The codes will eventually be available in printed form, both in a single volume and separately. Each code when printed as a monograph will be accompanied by the General Instructions, Definitions and Values, and pertinent selections from the section on Instruments and Apparatus and from the Appendices.

Special Instructions

No. 3. Committee on Fuels will formulate a code for the testing of all kinds of fuels, liquid and gaseous as well as solid, and will include the treatment of Flue-Gas Analysis, sampling, the determination of the fusibility of ash, etc.

No. 4. Economizers will be treated by Committee No. 4 on Boilers.

No. 7. Displacement Pumps do not include rotary displacement pumps. (See No. 8.)

No. 8. Centrifugal and Rotary Pumps include displacement pumps of the rotary type as well as those acting by centrifugal force.

No. 9. Displacement Compressors and Blowers include displacement compressors and blowers of all classes, rotary as well as reciprocating.

No. 12. Condenser Units and Feedwater Heaters. The title of this code has been changed to "Condensers, Water Heating and Cooling Equipment." This committee considers cooling towers, spray systems, etc., as well as condensing and heating apparatus proper.

No. 17. Gas and Oil Engines. The title of this code has been changed from the above to "Internal-Combustion Engines."

No. 18. Water Wheel Code. The title of this code has been changed to "Hydraulic Power Plants." This committee will prepare the code for testing turbines and all prime movers actuated by water.

No. 19. Instruments and Apparatus. This committee will prepare directions for the calibration, correction and application of instruments and methods for determining test values and conditions.

The Secretary of the Main Committee will furnish an account of the conclusions arrived at:

By any of the Individual Committees	to all members of the Main Committee
By committees 1 General Instructions 2 Definitions and Values	to all members of all committees
By committee 19 Instruments and Apparatus	to all members of all committees in the work of which the instrument or apparatus reported upon is involved

By committee 3 Fuels — to committees 4 Boilers, 11 Complete Power Plants, 15 Locomotives, 16 Gas Producers

The members of the Individual Committees have been selected with especial reference to their special knowledge of their respective subjects and it is the intention to have the codes when issued embody the best thought and experience of the profession. Advance proofs of each code will be sent to all who are qualified to discuss and constructively criticize them, inviting their comments before the code is issued. The members of the committees are widely distributed geographically and most of their work will have to be done by correspondence; it being impracticable for the Society to reimburse the many who are helping to carry out its purposes for expenses incurred in attending meetings.

Committee on Power Test Codes

Main Committee

*Fred. R. Low, *Chairman*
Edward T. Adams
*George H. Barrus
Oliver D. H. Bentley
*L. P. Breckenridge
William C. Brown
*Nathaniel A. Carle
*Robert H. Fernald
Edwards R. Fish
George J. Foran
*W. F. M. Goss
George R. Henderson
Francis Hodgkinson
Andrew M. Hunt
*David S. Jacobus
Edward F. Miller
Lewis F. Moody
James W. Parker
Richard H. Rice
James A. Seymour
Harry F. Smith
Frederick R. Still
Louis E. Strothman
Edward N. Trump
*William F. Uhl
Arthur West
*Albert C. Wood
C. B. LePage, *Secy.*

Individual Committees

1. *General Instructions*
W. H. Kavanaugh, *Chm.*
J. D. Andrew
G. H. Barrus
W. F. M. Goss
A. M. Greene, Jr.
C. F. Hirshfeld

2. *Definitions and Values*
R. J. S. Pigott, *Chm.*
T. W. Kinkaid
F. R. Low
L. S. Marks
S. W. Stratton
A. C. Wood
P. L. Wormeley (representing Dr. Stratton)

3. *Fuels*
C. R. Richards, *Chm.*
E. G. Bailey
L. P. Breckenridge
D. M. Myers
S. W. Parr
G. S. Pope
E. N. Trump

4. *Boilers*
E. R. Fish, *Chm.*
A. D. Pratt, *Secy.*
A. D. Bailey
W. N. Best
A. A. Cary
D. S. Jacobus
E. B. Ricketts

5. *Steam Engines*
W. C. Brown, *Chm.*
A. G. Christie, *Secy.*
G. H. Barrus
H. Cooke
H. Diedrichs
J. F. M. Patitz
F. H. Vose

6. *Steam Turbines*
J. W. Parker, *Chm.*
I. E. Moultrop, *Secy.*
F. Hodgkinson
W. J. A. London
S. A. Moss
R. H. Rice
C. C. Thomas

7. *Displacement Pumps*
L. E. Strothman, *Chm.*
C. H. Anderson
E. H. Brown
D. A. Decrow
G. J. Foran

8. *Centrifugal and Rotary Pumps*
L. F. Moody, *Chm.*
M. Spillman, *Secy.*
W. C. Brown
W. B. Gregory
M. B. MacNeille
F. H. Rogers
W. M. White

9. *Displacement Compressors and Blowers*
P. Diserens, *Chm.*
H. V. Conrad, *Secy.*
J. F. G. Miller
S. B. Redfield
C. G. Sprado
F. R. Still
C. P. Turner
J. T. Wilkin

10. *Centrifugal and Turbo-Compressors*
†S. A. Moss
J. E. Emswiler
H. F. Hagen
R. H. Rice
S. B. Redfield
C. H. Smoot

11. *Complete Steam Power Plants*
N. A. Carle, *Chm.*
B. R. T. Collins
A. R. Dodge
C. F. Hirshfeld
W. S. Monroe
J. W. Parker
A. A. Potter
F. L. Pryor

12. *Condensers, Water-Heating and Cooling Equipment*
G. J. Foran, *Chm.*
P. E. Reynolds, *Secy.*
C. H. Baker
E. W. Christie
R. N. Ehrhart
G. A. Orrok
M. C. Stuart

13. *Refrigerating Machines and Plants*
D. S. Jacobus, *Chm.*
L. Block
N. H. Hiller
F. E. Matthews
E. F. Miller
P. Neff
T. S. Shipley

14. *Evaporating Apparatus*
E. N. Trump, *Chm.*
B. N. Bump
E. A. Newhall
H. L. Parr
L. C. Rogers

15. *Locomotives*
E. C. Schmidt, *Chm.*
G. M. Basford
A. W. Gibbs
W. F. M. Goss
G. R. Henderson
G. E. Rhoads
J. M. Snodgrass
M. Toltz
C. D. Young

16. *Gas Producers*
W. T. Magruder, *Chm.*
W. B. Chapman
R. H. Fernald
G. J. Rathbun
C. D. Smith
H. F. Smith
C. L. Straub

17. *Internal-Combustion Engines*
C. E. Lucke, *Chm.*
E. T. Adams
A. E. Ballin
M. Rotter
J. A. Seymour
A. West

18. *Hydraulic Power Plants*
W. F. Uhl, *Chm.*
A. S. C. E.
N. A. Carle
B. F. Groat
C. Herschel
N. E. L. A.
C. M. Allen
A. C. Clogher
J. A. Walls
A. I. E. E.
H. W. Buck
H. A. Putnam
P. Torchio
A. S. M. E.
J. L. Harper
C. W. Larner
W. F. Uhl

19. *Instruments and Apparatus*
G. H. Barrus, *Chm.*
C. M. Allen
R. E. Dillon
C. F. Hirshfeld
G. A. Orrok
G. B. Upton

* Members of the Executive Committee.
† Temporary Chairman, Committee not yet organized.

TORPEDO-BOAT DESTROYERS IN THE MAKING

(*Continued from page 743*)

From a management standpoint, it is of value to note that the interest and enthusiasm of the working force who accomplished this feat were worked up and maintained by the men themselves. They produced their own cartoonists, banners, graphic daily records, and vaudeville stunts, and jealously guarded the industrious performance on the part of each workman. Not a man or boy was discovered loafing on any part of the work, and it was the usual thing for both mechanics and helpers to move "on the run" while employed on the *Ward*.

Reference has not been made in the above to the introduction of gas and arc welding in destroyer construction, but the progress along these lines has been such as to warrant the prediction that a very considerable amount of riveting work will in the future be performed by welding. At the present time certain bracket stiffeners are arc-welded on many vessels and similar means are being used for securing various deck fittings, such as cleats, bolts, chocks, bitts, trunks, etc. Also, gas welding and cutting are extensively used in the intricate stapling and other furnace work formerly tediously and expensively done by the anglesmith.

The development of the torpedo-boat-destroyer type is still in progress. The British Navy had in service during the war a vessel of the torpedo-boat-destroyer type but of about 50 per cent greater displacement. These boats are known as "flotilla leaders," that is, they are employed as the flagboats of destroyer flotillas or divisions. They carry a heavier armament, more power and the added personnel necessitated by their increased displacement over that of regular destroyers. Consideration has been given to the addition of units of this type for our service but no definite information is available as to the status of this question at the present time.

RECATALOGING THE U. E. S. LIBRARY

A Discussion of Interest and Value to the Profession Generally, Dealing with the Principles of Cataloging and Systems of Classification

To the Library Board
of the United Engineering Society.

Gentlemen:

In accordance with your desire to have a brief statement of the principles upon which it is proposed to recatalog the Engineering Societies Library, I beg to present the following account.

In order that the technical terms used may be clearly understood, some general definition of them is desirable. The principal purpose of library catalogs is to enable a reader to find a book of which either (1) the author, (2) the title, or (3) the subject is known; to show what the library has (4) by a given author, or (5) on a given subject; and to assist in the choice of a book, (6) as to its edition, or (7) as to its character.

An Author Catalog fulfills the 1st, 2d, 4th, 6th and 7th of these subjects. The *author* in a narrow sense is the person who writes a book; in a wider sense it is applied to him who is the cause of the book's existence, e.g., editor, translator, compiler, etc. Bodies of men, societies and countries are, from a cataloging point of view, considered the authors of their official publications, memoirs, transactions, journals, proceedings, reports, etc. All names selected as author names are arranged in strict alphabetical order.

A Subject Catalog fulfills the 3rd and 5th of the objects named above by entering or registering each book under the name of that subject or topic of which the book chiefly treats. It may or may not be alphabetical in arrangement. If the arrangement is not alphabetical the catalog is commonly called a Classed Subject Catalog, although this name might with equal propriety be applied to some alphabetical arrangements.

The present catalog of this Library is composed of several parts, as follows:

1 An author catalog, formed by interfiling the catalogs of the four constituent libraries
2 An alphabetical classed catalog covering three of the original collections
3 A classed subject catalog of the Library of the American Society of Civil Engineers
4 An alphabetically classed catalog supplementing No. 3 and acting as an index to it as well
5 A printed index to periodicals, published in 1915, and now vitiated by the changes that have occurred. These periodicals are not represented in Nos. 1 and 2.

It is proposed to substitute for these catalogs an author catalog and a classed subject catalog, the latter to be accompanied by a very full index.

Author Catalog

The nature of this catalog is best shown by a statement of the kind of entries that the books will be entered under. These are:

1 Full names of the author or authors, with identifying information when books by different individuals of the same name appear
2 Corporate entries; names of societies, organizations, countries, cities, etc., which are considered the authors of the publications issued in their name or by their authority
3 Titles of periodicals
4 Added entries, comprising the names of joint authors, editors, translators and other persons or bodies other than the one under whom the main entry is made, who had some connection with the making of the book.
5 Analytical author entries for books or articles contained in a collection, e.g., a volume of monographs by various authors, a series, a collection of reports, etc.
6 Cross-reference cards, referring from any form of a name under which a book may be sought, to that form which has been selected for the catalog. These cards take care of alternative, incomplete or foreign forms of names, variations in spelling, translation or transliteration.

The present author catalog, except for the omission of periodicals, is reasonably satisfactorily. Work upon it will be restricted to the addition of these, correction of errors, revision of the location marks, harmonizing of differences of method of entry in the original catalogs composing it and the insertion of additional analytical entries.

Subject Catalog

For the various alphabetical and classed subject classifications now extant it is proposed to substitute a single classed subject catalog in which the books will be arranged systematically according to their chief contents and to the classification adopted.

Classification has been defined as "the art of placing a book in that part of the library where all similar books on the same subject are placed." In a classed subject catalog it means the entry of a book in that place in the catalog where all similar entries on the subject are collected.

In the classification of books on the library shelves certain difficulties arise to prevent complete attainment of the ideal. The physical book can of course stand in but one place and the business of the classifier is to determine the group to which it belongs and place it there. It is a common thing, however, for a book to treat of more than one important subject. Books on water supply, for example, frequently have long chapters or sections on dams; similarly, books on steel making often give considerable space to rolling mills. These conditions make it impossible to collect the library's resources on the shelves.

It is the business of the catalog to furnish a means by which the reader who desires to see what the library has on dams or rolling mills is made cognizant of the valuable information contained in books treating of water supply or steel making, as well as of the books treating solely of the former subjects. This can be accomplished in the catalog by inserting additional entries at as many points as seem desirable, so that it will reveal the real resources of the library, insure the efficient use of all the books, and prevent the overlooking of important material germane to the subject under investigation.

The order in which our subject groups follow each other in the catalog will not be alphabetical but a systematic one, in which subjects are divided and subdivided in subordinate groups which succeed each other. As a guide to this arrangement an alphabetical index will be necessary, showing the location of each subject in the catalog. With it, it will be possible to ascertain without delay whether or not the library possesses books on a subject and where these are listed in the catalog.

When these catalogs are completed the catalog equipment of the Engineering Societies Library will be as complete, detailed and satisfactory as it is possible to make it. Our catalogs will be true and helpful guides for all reasonable methods of approach by readers. They will give the information that may properly be expected of them, and a little more. It must, however, be kept clearly in mind that it is not the province of a library catalog to do a reader's work for him or to indicate all possible or probable sources of information on a subject. This is decidedly not the case; but many persons too often approach a great reference collection with the expectation that the information they want and the precise form in which they want it are contained in the catalog or the heads of the assistants. It is common experience for readers to want a book or article treating a subject from exactly the angle or point of view in which they are for the moment interested. They will, for example, ask for a book on Materials Used in Pump Construction. No work exclusively devoted to this topic has, I think, ever been written. Information on these materials may, however, be found scattered through scores of works on the strength of materials, materials of engineering, pumping engines, metallurgy, etc. The work of collecting the scattered data is the duty of the reader and not of the catalog, which should only be expected to reveal the material on which whole books or articles have been written. In other words, the catalog cannot be expected to act as an index to all the books in the library.

The author catalog will enable the reader to find a book when the name of the author is known, to find what books by any author are in the library and also the various editions available; translations as well as their originals will be shown.

The subject catalog will enable the reader to find a book when the subject is known, and will exhibit the resources of the Library in orderly form on every chief and most suborbinate topics within its chosen field.

The alphabetical index will comprise the names of the subjects of knowledge upon which we possess important books or pamphlets, and it will at once direct the user to that section of the subject catalog where these books are listed and to the department of the Library where these works are shelved.

These three instruments, properly and patiently used, will give all the assistance that may fairly be expected of them. They will be guides and indicators, not dictionaries, or encyclopedias, but the latter functions should not be demanded of a catalog.

Classification

Two distinct but related problems in classification confront the librarian: the classification of the actual books in order to bring the volumes on each subject together on the shelves, and the classification of the cards representing the works in the library, so that its resources on any subject can be ascertained from the catalog.

It is obviously desirable that the same classification should be adopted for both these purposes; but it is not essential, and as a matter

of fact, some variations between the arrangement of the two classifications are found in most libraries, occasioned by local conditions that seem to warrant a deviation from the logical plan.

We propose to adopt the same classification for all our work, but in doing so it is the intention to keep clearly in mind the basic difference between the classification of the two kinds of material, due to their fundamental physical differences.

Books frequently treat of several subjects or the relations of two subjects to each other. One copy of a book can be shelved in but one place, with the result that only in the broadest sense can it be said that the books in any section of shelves contain the library's resources on a subject. If the books on the metallurgy of iron, copper, etc., are segregated under these specific headings, the alcove for electric furnaces cannot contain all the material on that subject. In the catalog this dispersal of material can be overcome by placing cards under both subjects, or under as many as may be thought desirable.

For many years librarians have been divided into advocates of "broad" classification and "close" classification. Those of the former party base their arguments on the expense of close classification, the impossibility of closely grouping the books on a subject and the cumbersome notation involved in the close classification of a large collection of books, causing frequent mistakes in replacing books on the shelves.

Those who favor close classification point to the saving of the readers' time resulting from it, especially in growing and large libraries.

The point of view adopted seems dependent upon whether classification on the shelves or in the catalog is actually in mind. Close classification in the catalog is undoubtedly desirable; on the shelves it is practically impossible.

In our work we intend to adopt a plan by which the classes on the shelves will be small enough to be conveniently surveyed by a reader, but not so small that extremely long location numbers will be necessary or that every book on a subdivision of a topic is actually touched by another book on the same subdivision; while at the same time the classification in the catalog will be carried to a point where it will be possible to locate a specific subject without examining much related matter.

The scheme of classification that seems best adapted for our needs as indicated above is the Dewey classification as extended and modified by the Institute International de Bibliographie, usually known as the "Brussels" classification, to differentiate it from its progenitor.

This classification follows Dewey's plan in the adoption of a decimal notation and in the arrangement of its main classes. Human knowledge is divided into nine classes and each is given a decimal number as .1, .2, .3, etc. The numbers beginning with .0 are reserved for encyclopedias, newspapers and other material too general in inclusion to be assigned to a specific class.

Each class is divided and subdivided as may be necessary, the location of the classes being indicated by the addition of numbers at the right of the class numbers, as is illustrated by the following example:

.6	Applied Science
.62	Engineering
.622	Mining
.6223	Exploitation of Mines
.62233	Of Coal Mines

This process can be repeated indefinitely.

The Brussels classification differs from the Dewey classification in two important particulars, one of which is a matter of minuteness, the other of form. As regards the first difference, it is probably sufficient to state that the published tables cover 2259 pages, in comparison with the 808 pages of the latest edition of Dewey. This extension of the tables permits a much closer direct classification of material.

The other change is much more important. One of the chief defects of the original Dewey classification is that, owing to the fact that it was planned primarily for the arrangement of books, it lacks certain apparatus needed in classed catalogs. It is not sufficiently minute for the latter purpose and it lacks a method for subdividing existing headings in order to express details, various points of view and the relations between different subjects. For example, it is sometimes convenient to separate the material on some subject into classes by date, language or thoroughness of treatment; or to separate the statistical works on a subject from the technical ones.

The Brussels classification provides for such needs by the addition of certain symbols to express relations and of detailed general tables of usual relations, which can be added to any subject by means of these marks. The symbols adopted are few, their position in the arrangement of items is clearly specified and their use carefully explained. They are outlined below in the adopted sequence.

Accretion Sign: The sign of addition, +, is issued to indicate that a book treats of all the subject number connected by it: e.g., 621.32-621.33, a book on electric lighting and electric traction.

Coupling Sign: The hyphen, —, is used in certain special cases to enable one subdivision within a class to be combined with another in the same class without confusion. The class number for agricultural land drainage is 63.11 and for forestry 63.49; the number 63.49-11 can be composed to indicate works on the drainage of forests.

Relation Sign: The most important of the symbols adopted is the relation sign, the colon, :. When used in the classification to join two numbers it indicates that the subjects represented by them are considered in relation to each other. It enables us to extend the classification to great lengths in order to express relations, without having to provide the apparatus in advance. Taking, for example, the number for rolling mills, 621.77, and the number 310, statistics, we can form the combination 621.77 :31 representing the statistics of rolling mills.

Form Sign: Divisions of the literature of a subject by form are made by using a parenthetic number beginning with zero, (0 ——). This is further divided into form divisions which can be used at any place, and divisions restricted to special subjects.

These forms enable the classifier to express such differences in the form of material as are represented by treatises, dictionaries, periodicals, histories, etc. A periodical on metallurgy has the number 669(05), a history of that subject is 669(09).

Examples of the special form division are 621.313(008), Patents on dynamos; 621.325(003), specifications for electric arc lighting; and 622(007) mining law.

Place Sign: Place is indicated by numbers which are written in parentheses and refer to a special geographical table. The table also provides for the differentiation of geologic periods. Examples are: 625(41) railways of Scotland; 621.19(73) steam-power plants in the United States.

Language Sign: Language divisions are indicated by the equality sign, =, followed by a number. We are thus enabled to divide a subject by language if we wish, as 62(05)= 44, French engineering periodicals.

Time Sign: It is sometimes convenient to specify time in our classification. This is done by adding the date in parentheses, as 623(09) "17", the history of military engineering in the eighteenth century.

General Points of View: The sign for these is a double zero, 00. The supplementary tables are:

001	Speculative: idea, plan, purpose, etc.
002	Realization: execution, construction, etc.
003	Economic: industrial production, cost, etc.
004	Service and use: workings, administration
005	Equipment and apparatus
006	Buildings and establishments; organization and service
007	Special personnel

Subdivisions are provided for these numbers.

These supplementary tables are especially useful for the classification of scientific material, such as that in the Engineering Societies Library. They enable us to indicate the point of view of any article when the main division to which it belongs lacks the necessary intention. They provide, for example, for such an analysis of material as

62163.0012	Theory of centrifugal ventilators
62163.0031	Manufacturing costs of centrifugal ventilators
62163.0042	Operation of centrifugal ventilators

As examples of the classification the following arrangements of material by form and by point of view may be interesting:

By Form

621.13	Locomotives
621.13(02)	Treatises on the locomotive
621.13(44)	Locomotives in France
621.13(5)	Locomotives in Asia
621.13 "19"	Locomotives in the twentieth century
621.13 : 622	Locomotives in mining
621.13 B	Baldwin locomotives
621.13.0014	Locomotive tests
621.13.04	Locomotive boilers
621.13.42	Locomotive valve gears

By Point of View

621.12	Marine engine		
621.120012	"	"	theory and calculation
621.120014	"	"	tests and trials
621.120022	"	"	methods of manufacture
621.120023	"	"	materials
621.120025	"	"	special machinery for making
621.1200272	"	"	mounting and assembling
621.120031	"	"	cost of manufacture
621.120035	"	"	prices
621.120042	"	"	management
621.120045	"	"	inspection
621.120046	"	"	deterioration and accidents
621.12005	"	"	fittings
621.12006	"	"	factories
621.120072	"	"	marine engineers

These examples illustrate the minuteness with which material can be classified if necessary, and the various forms of classification that may be used to meet special needs or the peculiarities of certain kinds of material. It is not necessary, of course, to introduce such great refinement in all cases, nor, in fact, in many, but the possibility of such subdivision, whenever desired, is very valuable.

A frequent objection to the decimal notation is the lengthy numbers that it requires. This objection is sound if the classification of books on library shelves is intended, for it is difficult to mark long numbers clearly on books, or to arrange these rapidly when so marked. The objection loses its force when the numbers are only used for filing cards in catalog trays, for these are not removed after having been once filed and there is also no necessity for copying the numbers.

(Continued on page 789)

ENGINEERING COUNCIL

Engineering Council[1] is an Organization of National Technical Societies of America, Created to Consider Matters of Common Concern to Engineers, as Well as Those of Public Welfare in Which the Profession is Interested

Activities of Council Representatives on Government Boards and Commissions

It is the desire of Engineering Council to be represented in all government bodies and commissions, and to that end the Council recently decided to urge upon President Wilson the appointment of one or more engineers to fill vacancies now existing in the Interstate Commerce Commission. Such representation would unquestionably prove of mutual benefit to the Interstate Commerce Commission and Engineering Council, and it is hoped that the President will approve of and act upon the suggestion offered.

Mr. Rudolph P. Miller, Mem.Am.Soc.C.E. and a consulting engineer of New York has been appointed as the Council's representative on the National Board for Jurisdictional Awards in the Building Industries. This board, whose function it is to settle disputes arising among the various parties engaged in the building industries, held its first meeting on August 11 in Washington, D. C. E. J. Russell of St. Louis, the representative of the American Institute of Architects, was elected chairman, and William L. Hutcheson of the American Federation of Labor vice-chairman. No further action was taken at this first meeting, as the cases on hand were not in the form required. They accordingly will be returned, to be resubmitted in the prescribed manner, and will be considered at the next meeting of the board, which will be held early in November.

Philip N. Moore, a past-president of the American Institute of Mining and Metallurgical Engineers, and the only engineer member of the War Minerals Relief Commission (see MECHANICAL ENGINEERING for May p. 489 and for July p. 634), is now engaged in holding in many of the western cities hearings of claims submitted to the commission. While thus engaged Mr. Moore has been the guest of several of the western engineering societies, and has been offered the opportunity of speaking before the engineers of Portland, Ore., Spokane, Wash., and Butte, Mont.

To the courtesies thus extended Mr. Moore has responded by discussing the activities of the Council and its efforts in behalf of the proposed Department of Public Works to which reference has frequently been made in MECHANICAL ENGINEERING.

Mr. Moore pointed out that the agitation for centralization of engineering work in this country is not new, but has been the hope of the profession for years. In fact, so much so that it has been given definite form many times when the question has been considered. A National Department of Public Works has therefore been proposed, and the profession is now again urging the creation of such a Department in which the engineering activities of the country will be brought together under one head instead of being dissipated as at present among many bureaus.

NATIONAL SERVICE COMMITTEE

Contributed by the Washington Office[2]

A Comment on the Department of Public Works

On October 28, 1884, Mr. Clemens Herschel, Mem.Am.Soc.C.E., published a pamphlet which contained the following statement:

> Let those who may shun the proper organization of the States and of the General Government for the systematic construction and maintenance of public works think of one thing: no nation has yet existed that was wholly without them, and this nation, no less than most or all of its states, in spite of all obstacles, has had them, and *is constantly having them*. The question becomes reduced then to this simple proposition: shall our public works be built, and, what is of equal importance, maintained, in a proper, business-like manner, getting year by year a dollar's worth for a dollar's expenditure, or shall the shiftless, hand-to-mouth method of procedure, which looks not forward, and hides its shiftlessness by denying that we have any public works—shall this wastefulness of the public funds be allowed to continue?"

Mr. Herschel is one of the few Public Works Department pioneers who still remain among us, and it will therefore be of interest to read what he has to say thirty-five years subsequent to the date of the foregoing. We accordingly quote from a recent letter to the National Service Committee:

> It appears to be no longer necessary, as I can well remember it was in times past, to argue that public works are an essential accompaniment of a civilized state. Formerly such works were, with us, called "Internal Improvements," and schools of political philosophers spent much time in proving, from their view of the Constitution of the United States, that private enterprise was all-sufficient, and consequently should be solely allowed to construct our public works; and again, the reverse of this proposition. That day has gone by. What Henry Clay thought about it, what those opposed to him wanted done on those lines, are both of small importance at the present day. This is a present-day nation of 110 million inhabitants: not a parcel of pioneer colonies, beginning to develop as a modern state. This is the year 1919; not 1819, when the building of the Wheeling turnpike, and of the Erie and other canals first brought the Government at Washington face to face with the need of a governmental executive agency, for the design and construction of public works; not to mention their repair, maintenance and operation, after they had been completed.
>
> In the emergency thus created, midst the clash of resounding rhetoric of the "strict constructionists" who denied the right or power of the United States to undertake any public works; and of the statesmen who argued for the development of the country by the aid of United States governmental agencies, was born the system still in vogue—at the time intended as a temporary measure—of calling upon the military branch of the Government to assume civil-engineering functions. It could not well then have been otherwise. There were no civil engineers in the country, or at least so few, that they formed no material part of the body politic.
>
> The first use of the word engineer, as is well known, came from the exercise of refined military work, and there were none but military engineers, as far as is known, until about 1780, which was some 40 years before the rise of the discussion concerning "Internal Improvements" in the United States.
>
> In 1782, "a Mr. Smeaton," as the law books have it, in the leading case of Folkes vs. Chadd, was called to give his opinion (not testimony) from the witness stand, and thus became the first "expert witness" in English court procedure. This was no other than the celebrated John Smeaton, F.R.S., and of many other titles; the builder of the renowned first built permanent Eddystone Light in the English Channel, and who was the first man to sign his reports as coming from a Civil (not military) Engineer, and thus, also, the first English-speaking "Civil Engineer."
>
> Forty years later, in America, there were, to be sure, surveyors—George Washington had been one of them—but no engineers that were noticeable, except the graduates of West Point, and other military engineers that had been imported for and had survived the Revolutionary War. And so the country turned for its civil engineering, for its turnpikes and canals, to the Department of War, and as an emergency measure designated members of the Corps of Engineers, U. S. Army, were temporarily detailed to supervise the construction of these works.
>
> The wide world over there are today but two systems of providing for the construction and operation of public works: first, either to ignore the necessity for their existence in a civilized state, and thus provide for them by emergency measures; or second, to consider them as forming part of the every-year work of the government of a civilized state, and provide for them in the fundamental law governing such states, in the same way that Departments of War, Navy, Treasury, and even the bodies exercising police powers or the judiciary are provided.
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> Under the first caption come Great Britain and her dependencies, but even these do not call upon the Royal Engineers (corresponding to our Corps of Engineers, U. S. A.), unless exceptionally to approve the construction of a new railroad, before it is opened for travel.

[1] Officers of Engineering Council; J. Parke Channing, *Chairman*; Alfred D. Flinn, *Secretary*, Engineering Societies Building, 29 West 39th Street, New York.

[2] Washington Office in charge of M. O. Leighton, *Chairman*, National Service Committee, McLachlen Building, 10th and G Streets.

Under the second caption comes each and every European continental country, and, so far as I am informed, the civilized countries of all the rest of the world.

The great exemplar of relying for all public works upon private enterprise, is England. When public works had to be built, harbor works, works of water supply, metropolitan sewerage, and others, the emergency system was followed. For each case a select body of laymen, a so-called commission, would be appointed, and an emergency corps of civil engineers gathered as an executive agency. The commission would studiously, and in some measure, qualify itself for its task, works would be executed, and the whole organization would then dissolve into its original elements. Of course there are exceptions to and variations from this normal state of affairs. And England, it may be said, has grown heartily tired of its want of organization for purposes of constantly recurring and as constantly necessary work, which has been described. The light is beginning to break in upon her, as it must also sooner be apparent to the United States.

The second method for a state to care for its public works a host of our civil engineers and others have no doubt recently seen in operation, even in war times, in France and in other European countries. The Minister of Public Works, an important member of the Cabinet, stands at the head of the organization. In the United States, let me say at once, the Secretary of the Interior could without much disturbance, be converted into such a Secretary of Public Works.

The great change that must come, if public works are to be economically and efficiently designed and constructed, is that of constituting a permanent corps of civil engineers to do the civil-engineering work of the country, under a Secretary for Public Works such as described. It is the only efficient way. Organizations built up as emergency measures must give way to it.

It is its permanence of organization, the holding of like service to the Government, that has always given the Corps of Engineers the respect of the President and Congress. A commissioned corps of U. S. Civil Engineers would equally have the respect of the President and of Congress. It would also and to the same extent have the *esprit du corps*, the trustworthiness and the like desirable attributes that naturally belong to and go with a fixity of tenure of office, and with governmental responsibility.

The Secretary for Public Works and his corps of civil engineers once organized, other and allied work of the Government not already there would naturally come to the same department: for instance, the Geological Survey, Bureau of Mines, Bureau of Standards. Once form a Department whose chief functions are those of civil engineering, and the perfection of its organization and its power to do efficient work for the United States would naturally follow.

The Coast and Geodetic Survey

It is the function of the Coast and Geodetic Survey to chart the coast lines and the waters of the United States and its possessions; make studies and prepare tables and charts of tides and currents; to provide an accurate triangulation control of the interior of the United States; to establish precise level stations; and to make magnetic surveys for the determination of true declination.

The history of the Survey shows that it has been under the Treasury, Navy and Commerce Departments, and that it is now following out a general policy laid down in 1843 while it was subordinate to the Treasury Department. Its early years were marked by many changes of policy and of authority and by little effective work. The survey of the coasts was first authorized by Congress on February 10, 1807. Broad plans for the conduct of the survey were made by F. R. Hessler, a scientist of Swiss birth, and the Treasury Department was made responsible for carrying out these plans. Precision instruments were not available, however, in this country, and had to be secured from abroad, and this, together with the war with Great Britain in 1812, delayed all work on the survey until 1816.

The Survey had barely begun its work when Congress, on April 14, 1818, repealed much of the statute authorizing the employment of other than Army and Navy Officers in the Survey. The War Department made no surveys and the work of the Navy Department was also quite unsatisfactory and so, on the recommendation of the Secretary of the Navy and of others, this Survey was given back to the Treasury Department by Congress in July, 1832, and the law of 1807 with broader powers was reenacted.

The Survey remained under the Treasury Department only two years and in March, 1834, was again transferred to the Navy Department under whose jurisdiction it remained for a similar period, and then was again given back to the Treasury Department, where it remained until July 1, 1903. It was then placed under the Department of Commerce by Act of Congress approved February 14, 1903.

In 1843, while this Department was still under the Treasury Department and the question of retransference back to the Navy Department was being discussed, the President appointed a board to formulate and develop a plan for a permanent organization of the Survey. The report of this board was approved by the President on April 29, 1843, and the work of the Survey has ever since been modeled along the lines then laid down. After the adoption of this report until the war with Spain in 1898, nearly one-half of the vessels of the Survey were manned and officered by the Navy, but since that time the civilian officers and employees of the Survey have officered and manned all vessels.

The results of the Survey's work are made use of by commerce, by the railways, by land owners of every kind and by all enterprises whose primary investigations require the use of maps. The placing of all of these surveys, therefore, whether by land or by sea, under the proposed Department of Public Works would insure a comprehensive mapping plan, the use of consistent scales and legends on all maps, and would bring together a permanent corps of skilled surveyors who would be capable of mapping the interior of the United States with such exactitude as would make their results of unlimited value in time of peace as well as in time of war.

Instead of twelve independent bureaus making surveys, each without liaison with the other eleven bureaus, there would thus be one central department planning and conducting this work, weighing the comparative needs of different sections, and so directing the efforts of the department that the greatest good to the greatest number would result. There is no work that this Survey does that will not fit in with the work planned for the Department of Public Works. It is essentially an engineering work and consequently belongs in the National Department of Public Works together with the other engineering activities of the Government.

The Proposed Department of Aeronautics

Aeronautics is to come in for special governmental attention if the bill providing a Department of Aeronautics is established. The proposed Department will be headed by a Secretary of Aeronautics at $12,000 per annum and an assistant at $5,000 per annum. A commissioned personnel of approximately 5000 and a non-commissioned personnel of approximately 50,000, together with a large number of civilians to carry on the commercial work is also proposed.

The Aviation Section of the Signal Corps; the Division of Military Aeronautics; the Bureau of Aircraft Production; the Air Service of the Army; the Motor Transport Corps; the Naval Flying Corps; the Marine Corps Flying Corps, and the Aerial Mail Service are all to be transferred to this new proposed Department. With each will go their respective clerks and other civilian employees.

It is to be the duty of the new Department to foster, develop and promote all matters pertaining to aeronautics, including purchase, manufacture, maintenance and production of all aircraft for the United States, and to lay down rules and regulations to govern aviators and aeronautics in general. The Department is to establish and supervise aerial landing fields for both military and commercial purposes, and is to care for the coast, border and forest reserve patrol. An aeronautic academy is also to be established.

The Engineering Division under the Secretary of Aeronautics is to select types and designs of all aircraft equipment, including ordnance and communicating equipment, and is to care for the repair and maintenance thereof. The Division is also to operate and maintain aircraft factories, repair shops and experimental stations. Aerial photographic apparatus will likewise be developed by this Division, with which aerial photographic maps of the United States and its territories are to be made and provided for the public good.

NATIONAL RESEARCH COUNCIL

The National Research Council is Devoted to the Advancement of Research in the Mathematical, Physical and Biological Sciences, and in the Application of These to Engineering, Agriculture, Medicine, and Other Useful Arts

DIVISION OF ENGINEERING

DR. HENRY M. HOWE, who recently returned from Paris, where for three months he served as Scientific Attaché to the American Embassy, has made public, in a recent report to the Division of Engineering, a brief account of his activities during his stay abroad. While in London, on his way to Paris, Dr. Howe states that he was able to interest many in the work of the National Research Council, and in particular to explain its aims and needs to the Council of the Department of Scientific and Technical Research. Dr. Howe also took steps to bring about coöperation between the National Physical Laboratory and the Committee on Fatigue Phenomena of Metals of the Division of Engineering in their work dealing with the heat treatment of carbon steel and with alloy steels.

Dr. Howe was further instrumental in arranging a meeting, under the chairmanship of Dr. Unwin, at the Institution of Civil Engineers, which considered the formation of an International Association for Testing Materials which should carry on the work formerly done by the old society of that name. This meeting was attended by a large and distinguished body of unofficial representatives of many important engineering bodies. It was thought best to call a second meeting of official delegates of these societies, and at this meeting it was decided that the time was not yet ripe for action.

In Paris Dr. Howe consulted several of those best qualified to pass judgment on the question of an international testing society, among them being Professor Le Chatelier and Professor Mesnager, Vice-President of the old International Association for Testing Materials. Their attitude also inclined toward the belief that the decision reached in London was proper.

From May 20 to 23 Dr. Howe took part in the meeting of the Executive Committee of the International Research Council, which formulated more fully the work of that Council and arranged for its first regular meeting, which was held in Brussels during July.

The Division of Engineering now has twenty-one committees engaged in research. Fifteen of these deal with metallurgical subjects, four with civil engineering, one with mining engineering, and one with electrical engineering. Progress reports of all of these committees are now available.

Committee on the Fatigue Phenomena of Metals. The total number of fatigue tests made thus far by the committee is about 90, with the number of repetitions of stress running up to 2,000,000 and 3,000,000. There have been filed with the committee records of fatigue tests of metals made in various governmental and commercial laboratories, and these will be of service in establishing and in checking conclusions. Records of about 100 such tests are now on file.

Because of the change to peace conditions an entirely new and comprehensive program has been adopted, and this should yield results of the first importance. A very valuable report on the present status of our knowledge of fatigue has been prepared by the committee and will be found elsewhere in this issue of MECHANICAL ENGINEERING.

The Engineering Foundation is to give $15,000 a year for two years to the work of this committee. This will be carried out in large part at the University of Illinois, which contributes for two years the use of its laboratories and the services of Professor Moore. This contribution is estimated conservatively as the equivalent of $6000 a year. The University reserves the right to publish the results in its own bulletin.

Committee on Improvement of Metals at a Blue Heat. It has long been known that working steel at a blue heat and even simple exposure to blue heat under certain conditions, may injure it seriously. This committee investigates this general subject and the influence of exposure and treatment at temperatures below the transformation range on the properties of steel. Three important reports have been issued, and these bring together and analyze a large amount of new information, much of which is as yet unpublished.

The committee has outlined considerable work for the future, and will study among other things the physical properties of boiler-plate steel at high temperatures—reaching approximately 1000 or 1200 deg. fahr. (540 to 650 deg. cent.), the tempering temperatures of high-speed steel, and the quenching of various alloy steels from a blue heat.

Committee on Pyrometry. It is the purpose of this committee to investigate improvements in pyrometry, including the measurement of the temperature of the bath of steel in the open-hearth and electric steel-making processes. Direct experiments have been made at the Midvale Steel Works with an optical pyrometer sighted on the bottom of a closed tube of refractory material immersed in the bath. A suitable material for this tube has not yet been found. For the tip of such a tube Acheson graphite is the best material thus far found.

The committee finds that the Burgess method of taking a series of readings with an optical pyrometer of the temperature of a stream of molten steel, poured from a hand ladle and calculating back to the temperature at the moment of dipping the ladle, gives trustworthy results with an accuracy of 10 to 20 deg. cent. Other methods to be tested are: (1) to determine optically the temperature of a plug of Acheson graphite immediately after immersion in the steel for a fixed time, and (2) to determine optically the temperature of the immersed end of a fused quartz rod or tube immersed in the metal. The transparency of the quartz permits us to see its immersed end, and thus to measure its temperature optically.

The committee has caused sixty-six papers on pyrometry to be written. Of these fifty-seven have been accepted by the American Institute of Mining Engineers, and will be published as a symposium on pyrometry in a separate volume. This symposium is the most important event in pyrometry since the invention of the Le Chatelier thermoelectric pyrometer.

Committee on Substitute Deoxidizers. The original purpose of this committee was to find ways of saving manganese by replacing the iron-manganese alloys now used for deoxidizing steel made by the bessemer, open-hearth and electric processes. It is of the first importance that the oxidized products resulting from the use of such alloys should be readily fusible and fluid, so that they may separate readily from the molten steel. Hence the first work of this committee was to determine systematically the melting points of the oxidized products of the alloys of promise for this purpose. A new method of determining melting points was devised. About one-third of this work has now been done, and steps are to be taken to complete it.

Committee on Welding—Research Committee of the American Bureau of Welding. This committee succeeds the old Welding Research Sub-Committee and the Sub-Committee on Metallurgy of the Welding Committee for the Emergency Fleet Corporation. The purpose of the committee is to carry on the research work inaugurated by the two former committees. They expect to cover the whole field of research in welding, including electric, gas and spot welding. A great deal of useful work was accomplished by the old committees, which derived their financial support from the Emergency Fleet Corporation, whereas the new committee intends to secure support and coöperation from those interested in welding through the medium of the American Bureau of Welding. It is believed that the new committee will continue vigorously the fruitful work of the old.

Committee on Elimination of Sonims (Inclusions) of Steel. It is the purpose of this Committee to study the sources, methods

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of occurrence and effects of sonims (solid non-metallic impurities), as well as means for eliminating them from steel. The methods employed are: First, to procure samples of good and bad steels and determine the total sonims; and second, to examine them microscopically to determine their shapes and sizes and ascertain their proximate and ultimate composition. Methods for separating them must also be worked out, solution of the soluble metallic part of the steels being effected by iodine, double chloride of copper and ammonia, dilute acids, electrolysis or other means.

The aid of several of the steel companies has been enlisted, and a number have worked on the scum which gathers on ingot tops of low-carbon effervescing steel. This has been shown to be chiefly formed of sonims which have collected from the molten steel. It is now proposed to form a syndicate of beneficiaries of such an investigation.

PULVERIZED COAL AS A FUEL FOR BOILERS

(Continued from page 749)

subordinate to the performance of the boiler; and just as the design of boiler is varied to satisfy the steam requirements, so must the furnace proportions and mode of burning coal vary to supply the necessary gases for the efficient operation of the boiler, and in so doing, secure the greatest fuel economy.

The nature of fuels plays the all-important part in the efficiency and performance of furnaces, regardless of their calorific value. By pulverizing and proper treatment all grades of coals may be dealt with on the basis of their burnable content, thereby rendering their use equally applicable to all heating services.

DESIGN OF PULVERIZED-FUEL FURNACE FOR A 500-HP. BOILER

To demonstrate the possibilities of pulverized fuel along the lines indicated, a furnace for burning efficiently all grades of coal from the average best bituminous and anthracite qualities to lignite, and of such size as would be applied to a water-tube boiler of about 500-hp. capacity, has been designed, particulars being given in the following paragraphs.

In working out this design for a boiler with a steam pressure of 175 lb. and operating at 100 per cent and 200 per cent rating, consideration has been given to the best features of furnaces successfully burning pulverized coal and fuel oil. The temperatures of the gases as delivered to the boiler have been assumed to be 1800 deg. fahr. and 2750 deg. fahr., respectively, for the two ratings, the boiler efficiency being taken at approximately 80 per cent in both cases.

The purpose of this design is to study the possibilities of meeting as severe demands as are made at the boiler ratings selected, using all grades of powdered fuel. Fig. 4 shows two views of the furnace and Fig. 5 the gas performance of three different fuels.

The distinctive features of this furnace are the delivery of the fuel mixture and of the dilution air to insure perfect combustion, to permit regulation of the fire, and to guard against the slagging and destructive difficulties heretofore encountered. The air is supplied by suitable blowers and is heated before use by the waste flue gases for fuel mixing and by the body of the furnace for dilution purposes.

Regulation is accomplished by control of the fuel and of the air, the fuel-mixture spout outlets being proportioned to deliver, at maximum duty, a mixture containing 75 per cent of the air required for perfect combustion.

The purpose of the air jets *c* (Fig. 4) under the flame is to blow toward the ashpit the ash particles that may fall from the flame as well as the partially consumed particles of fuel. The latter are brought into the deflagration zone with a fresh supply of air and given a new chance to burn completely.

The rows of air jets *d* on top of the flame are for the purpose of directing the flame over a longer path and providing thereby longer time for the complete oxidation of the fuel particles, protecting the furnace from the hottest portion of the flame and aiding in the precipitation of ash toward the ashpit. Aside from supplying additional combustion and dilution air, the joint effect of the two rows of air jets is to carry the flame in *suspension*, away from the furnace walls and the ash deposit, and fulfill thereby one of the chief requirements for burning pulverized coal.

The idea of precipitating the ash by rapidly expanding the flame into a large space is applied, but it is not expected that all the ash can be thus collected. Some of the ash dust will be carried by the gases and deposited on the boiler tubes and surfaces beyond the hearth and must be blown off occasionally by soot blowers to a collecting hopper in the rear chamber of the boiler setting, from which it is discharged in a manner similar to that employed in removing the ash from the furnace.

The furnace design presented in Fig. 4, though possessing good features, is not necessarily typical. In an actual case the conditions of the service would influence largely the most suitable arrangement.

Furnaces for burning pulverized fuel demand careful consideration, not so much on account of the novelty of the fuel, but because, like other fuels, it possesses its peculiarities, which do not obey a general rule and which must be carefully considered to secure the maximum of usefulness for each kind and size of service.

AIRPLANE-WING DESIGN

(Continued from page 730)

apply them to conditions where the speed obtained is as great as 600 miles per hour. While the use of scaling rules and empirical factors worked out in practice has enabled us to produce very fair results, the need for accurate data has been pressing.

The high-speed wind tunnel operated by the Technical Section of the Department of Military Aeronautics is of the venturi type and shows an exceptionally uniform flow at all speeds up to about 500 miles per hour. The flow is produced by means of an especially designed 24-blade propeller which produces a suction of about 16 in. of water at the large end of the venturi.

An extensive series of experiments has been started on propeller airfoils in order to determine the effect of speed on the lift and drag coefficients.

It is desired to call attention to the fact that it is not sufficient to understand and be able to calculate the circulation about a horizontal axis perpendicular to the direction of motion; there are also very important vortices about axes parallel to the direction of motion. These are particularly apparent in the form of tip vortices. Their intensity might be estimated similarly to the calculation for fore and aft circulation.

F. E. CARDULLO.[1] As I understand the theory which Mr. Durfee is attempting to develop, instead of considering the reactions due to the acceleration produced under the action of the motion through the air of a plate, which may be straight or curved, he considers these reactions from the standpoint of the Bernoulli theory, on the basis that differences in velocity of air relative to the plate will exist on its two sides, and that in consequence to these differences there will be a difference of pressure and a lifting force. As a result, he points out that there are certain vortex motions at the ends and at the trailing edges of the plate. The problem is to reduce these vortex motions to a minimum so that the air comes from the plate in a stream, the filaments of which are as nearly parallel to one another as possible. The best method of attack would seem to me to be that of testing wing sections either by the emission of smoke from a fine orifice or with threads attached to needles. This method gives an opportunity for studying the vortices which represent irregular motion and lost energy. Mr. Durfee prefers to attack the problem from the standpoint of the investigation of these stream lines and velocities rather than the development of the theory of the reaction on the surface produced by acceleration. I do not know that there is much choice in the mathematics of the two methods, but in either case the mathematics is too difficult to offer a practical solution.

[1] Engineer of Tests, Curtiss Aeroplane & Motor Corpn., Buffalo, N. Y. Mem. Am. Soc. M. E.

ANDREW CARNEGIE

ANDREW CARNEGIE, philanthropist and one-time steel master, whose generosity made possible the erection of the Engineering Societies Building and that of the Engineers' Club, died August 11 at his summer home near Lenox, Mass., in his eighty-fourth year.

Mr. Carnegie was born in Dunfermline, Fifeshire, Scotland, on November 25, 1837. When eleven years old his father, a master weaver, suffered such reverses through the introduction of the power loom that he decided to abandon his occupation and emigrate to America with his wife and two sons. Settling in Allegheny City, the father and son found work in a cotton mill, the latter as a bobbin boy at \$1.20 a week. A year later Andrew obtained employment in the bobbin factory of a distant relative, John Hay, where he fired the boiler, and ran the engine. At the age of fifteen he became a messenger boy for the Ohio Telegraph Company and a short time later had perfected himself as an operator. When the Pennsylvania Railroad decided to install its own telegraph lines, in 1854, he became clerk under Thomas A. Scott, then superintendent of its Western Division. When the Civil War broke out he was assigned to duty in and around Washington, where he was instrumental in devising a war cipher system that was later adopted. In 1863 he had been promoted to the superintendency of the division, and, largely because of the interest which Mr. Scott took in his fortunes, had been successful in a number of business investments, notably oil and the Woodruff sleeping car.

Mr. Carnegie first became interested in the iron industry in 1864, when he bought a one-sixth interest in the Iron City Forge Company. Foreseeing a great demand for structural iron to be used in railway bridges, he also took part in organizing the Cyclops Iron Co., a rival to the former concern. A year later, however, the two companies were merged as the Union Iron Mills Company with a capital of \$500,000. Mr. Carnegie then organized another company, the Keystone Bridge Works, which was prosperous from the first. Into it he drew Colonel Scott, at that time vice-president of the Pennsylvania Railroad, and J. Edgar Thomson, its president.

In 1867 he was sent to England by the Pennsylvania Railroad to sell about \$9,000,000 in bonds. While in that country he saw a giant bessemer converter in operation and investigated the process. From that moment his vision was steel. He returned to Pittsburgh and organized the firm of Carnegie, McCandless & Co., the first step being the purchase of a 110-acre tract at Braddock, a dozen miles or so outside of Pittsburgh, where a bessemer plant was promptly erected and named the Edgar Thomson Steel Works.

In 1874 Mr. Carnegie began to realize abundantly on his efforts. The year before the first of the famous Lucy furnaces had been built, to be duplicated two years later, when they forced up the average output of iron from fifty to a hundred tons a day.

As the profits mounted one by one Mr. Carnegie's partners dropped out and by 1881 he owned more than half of the entire business. A reorganization was then undertaken under the name of Carnegie Brothers & Co. The new concern was a \$5,000,000 affair, with Carnegie at the head. It operated the Edgar Thomson Steel Works, while a second limited partnership called Carnegie, Phipps & Co., operated the Homestead Mills, the armor-plate mill near the same plant, the Keystone Bridge Works, and other properties. A few years later Phipps and Carnegie alone remained of the original fourteen partners, and in 1888 Mr. Carnegie found himself in control of seven great iron and steel works, whose output was estimated to be in the neighborhood of 190,000 tons of steel rails and 140,000 tons of pig iron a month.

For two years from 1899 the Carnegie Steel Company dominated the industry, but in 1901 it was absorbed by the United States Steel Corporation for \$460,000,000. The same year Mr. Carnegie retired from business with a fortune estimated at \$250,000,000.

Mr. Carnegie's Donation to the Engineers

Mr. Carnegie was early invited to take an interest in a building for the American Institute of Electrical Engineers, but without success for the reported reason that he felt the building which had been planned to be inadequate. Somewhat later, on account of his interest in libraries, he was approached to contribute to the amount necessary to abstract and catalog the Sir Latimer Clark Collection which had been presented to the Institute and which was mainly in Latin, many volumes being written by hand on parchment. Scarcely any volume was less than one hundred years old and many over three hundred.

It was in connection with a banquet, at which Mr. Carnegie was the guest of honor, given by the Institute under the auspices of its Library Committee, that Mr. Carnegie's interest in a union building was aroused. On the day following the banquet he sent for the chairman of the Institute's Building Committee, Mr. Calvin W. Rice, now secretary of The American Society of Mechanical Engineers. Mr. Rice and Mr. Charles F. Scott, then president of the Institute, called upon Mr. Carnegie, who expressed an interest in the addresses of the previous evening and in the work of the engineering societies.

Anticipating the line of questioning which Mr. Carnegie would be likely to follow, information had been secured upon the number of engineering societies in the city of New York and the amount of rent in the aggregate annually paid by these societies for their respective headquarters. There were then over thirty prominent societies and the gross annual rents amounted to over \$75,000.

Mr. Carnegie always gave in the same businesslike manner that he conducted any enterprise. He never gave unless there was every prospect that his gift would make successful and efficient an already promising activity. He consequently wanted assurance that a union engineers' building could and would be maintained and also that the societies would be able to purchase the land, which was another uniform requirement in Mr. Carnegie's gift of buildings.

An estimate of the cost of a union building had been made, so that when Mr. Carnegie inquired the cost Mr. Rice was prompt to say "one million dollars."

Mr. Carnegie replied "that is a lot of money," to which Mr. Rice said, "You would not wish to be identified with anything not creditable to you." Mr. Carnegie immediately assented, adding, "if it should cost \$7.50 more, never mind."

The original plan for a union building placed the Engineers' Club in the upper floors, much like the Transportation Club in the Manhattan Hotel, but it later seemed best to erect two buildings, principally on account of the Club's property being taxable and the Engineering Societies' property non-taxable. It therefore became necessary to ask Mr. Carnegie to increase his gift sufficiently to provide for separate buildings, and Mr. Rice made a trip to Europe, visiting Mr. Carnegie at Skibo, and successfully presented the desire of the Societies and of the Club for an additional \$500,000.

One of the interesting incidents in connection with the purchase of the several contiguous lots for the Engineering Societies Building was the demand by an elderly lady of \$100,000 cash before noon of the day the negotiations were consummated. Mr. Carnegie saw the humor of the situation and loaned the representatives of the Societies ten ten-thousand-dollar bills.

Mr. Carnegie's motive in this benefaction was both appreciation of the engineer's contribution to his personal success and the desire to promote the solidarity and coöperation of all branches of the engineering profession. "Coöperation," he said, "is America's secret of success."

The cornerstone of the Engineering Societies Building was laid on May 8, 1906, the Council of the Society being present by invitation. The building was brought to completion in the following spring and impressive dedicatory exercises held April 16 and 17, 1907. At the close of these exercises a bronze bust of Mr. Carne-

gie, presented by the past-presidents of the Founder Societies, was unveiled in the Library.

The inaugural banquet of the Engineers' Club on December 9, 1907, was made the occasion for conferring honorary membership on Mr. Carnegie, John Fritz, honorary member and past-president, making the presentation speech, and T. Commerford Martin, president of the Club, receiving the certificate from the President and Secretary of the Society and tendering it to Mr. Carnegie. The latter in accepting the certificate generously acknowledged his indebtedness to the engineer, and expressed heartfelt appreciation of the honor conferred upon him. Mr. Carnegie had been a member of the Society since 1890. He was also elected a member of the American Institute of Mining Engineers in 1888 and an honorary member in 1905.

Mr. Carnegie's Literary Work, His Honors, and His Benefactions

Despite the demands of business, Mr. Carnegie found time for literary work and wrote several books as well as a number of essays on economic and philosophical subjects for the magazines and reviews. His first work, published in 1883, was An American Four-in-Hand in Great Britain. In 1884 he wrote in Round the World an account of a trip he had made. Among his other writings are: Triumphant Democracy (1886), The Gospel of Wealth (1900), The Empire of Business (1902), The Life of James Watt (1906) and Problems of Today (1909). Triumphant Democracy, his best-known work, passed through eight editions and has been translated into eight languages. In it Mr. Carnegie treated of the progress of the American Republic largely as an advance in material prosperity, which he regarded as the surest test of the validity of the claims of popular government to superiority.

Mr. Carnegie received honors and decorations from rulers and people all over the world. He received as a result of his benefactions abroad the freedom of fifty-four cities in Great Britain and Ireland. He was Lord Rector of St. Andrew's University from 1903 to 1907 and of Aberdeen University from 1912 to 1914, and held the honorary degree of Doctor of Laws from the universities of Glasgow, Edinburgh, Birmingham, Manchester and McGill, as well as from Brown, Pennsylvania, Cornell and other American colleges. In addition to his connection with our Society and with the Mining Engineers, he was a member of numerous philosophical, civic and scientific bodies, among them being the American Institute of Architects, the National Civic Federation, the American Philosophic Society, and the New York Chamber of Commerce. He was commander of the Legion of Honor of France, and had also received the Grand Crosses of the Order of Orange, of Nassau, and of the Order of Daneborg.

Holding as his gospel of wealth that the millionaire should be but a trustee for the poor, "entrusted for a season with a great part of the increased wealth of the community, but administering it for the community far better than it could or would have done for itself," Mr. Carnegie established six great institutions for the furthering of those philanthropic causes which most appealed to his interest. The Pittsburgh Institute, the oldest of the six, was founded in 1896, the Research Institution at Washington in 1902, the Hero Fund in 1904, the Foundation for the Advancement of Teaching in 1905, the Peace Endowment in 1910, and the Carnegie Corporation of New York, with an endowment of $125,000,000, in 1912.

The Carnegie Foundation for the Advancement of Teaching was the outcome of Mr. Carnegie's sympathy with the cause of education and his desire to be of service to the teachers of America. The act of incorporation obtained by Congress enabled the Foundation to receive and maintain funds for paying pensions to college teachers in the United States, Canada and Newfoundland, and "in general to do and perform all things necessary to encourage, uphold and dignify the profession of the teacher and the cause of higher education." Seventy-four institutions of higher learning, seventy-one in the United States and three in Canada, have been admitted to the list of associated institutions. In these colleges, universities and technical schools there were on April 1, 1917, 6593 teachers, including professors, associate or assistant professors and instructors. Of these 715 were women.

The largest of Mr. Carnegie's single gifts was that creating the Carnegie Institute of Pittsburgh. This gift to the city of his prosperity called for a total outlay for building equipment and endowment of over $25,000,000.

Mr. Carnegie's benefactions amounted in all to more than $350,000,000, among the more important ones being the following: Library buildings (over 3000), $64,000,000; church organs (over 7500), $6,200,000; Carnegie Corporation, $125,000,000; Carnegie Foundation, $29,500,000; Carnegie Institute, $26,700,000; Carnegie Institution of Washington, $22,300,000; hero funds, $10,500,000; Scottish universities, $10,000,000.

One of Mr. Carnegie's greatest ideals was the abolition of war, a hope that he cherished in the face of international conflicts. He gave $10,000,000 toward an International Peace Fund, and at a cost of $1,500,000 built the peace palace at The Hague, which was dedicated in 1913. He also gave $750,000 for the Bureau of American Republics at Washington.

Resolutions by the Trustees of the U. E. S.

On August 14, 1919, the following resolutions relating to Andrew Carnegie were passed by the Trustees of the United Engineering Societies:

Andrew Carnegie's death August 11, 1919, at Lenox, Massachusetts, brought to its close a career which greatly advanced all the engineering arts and sciences. By the introduction into the United States of the bessemer process for the production of steel and by the establishment and development of steel plants, which became the greatest in the world, he made available for engineers the most useful modern material for engineering construction. In the successful conduct of many industrial enterprises he amassed great wealth, the possession of which he came to regard with deep seriousness as a public trusteeship. He devoted himself to the distribution of large portions of his fortune to projects for the benefit of mankind. He distributed his wealth not only in many directions, but also with the exercise of great wisdom based on careful investigation. His munificence provided large funds for the building of a home for the great national engineering societies and many associate societies. He was an honorary member of the American Institute of Mining and Metallurgical Engineers and American Society of Mechanical Engineers. He was personally known and loved by many engineers. In view of these facts, be it

Resolved, That the American Societies of Civil, Mining, Metallurgical, Mechanical and Electrical Engineers, the United Engineering Society and the Engineers' Club, herein express to the family of Mr. Carnegie and record their sincere appreciation of the great contributions of Andrew Carnegie to the advancement of engineering, and of his friendly assistance in making possible beautiful homes for the Engineering Societies and the Engineers' Club, thus fostering the spirit of unity in the profession.

Recataloging the U. E. S. Library

(*Continued from page 783*)

An incidental advantage of this classification, but one which is not to be despised, is its wide use. The Dewey classification is used more generally by libraries than any other classification, and the Brussels classification has found greater favor than any other for indexing and cataloging. The latter is now used by a number of Belgian and French magazines to classify the abstracts which they publish and was in use by several other organizations that suspended during the war. It has more international acceptance than any other system and its principles and notation are quite generally understood. The fact that many users of the catalog will have some previous familiarity with its system will enable them to use it more readily and with less assistance.

This outline of the proposed plans is incomplete; many points having been omitted in the desire for brevity upon a subject of considerable magnitude. It is hoped, however, that it will demonstrate to you that the system is sufficiently comprehensive and elastic to meet successfully any demand that this library may have to place upon it. It is also hoped that it will show that the preparation of an efficient catalog is not an easy task, but one requiring professional skill, good judgment and the expenditure of a considerable sum of money. Many library catalogs are unsatisfactory because this has not been realized, and efficiency has been sacrificed in an attempt to do the work too cheaply. The catalog is part of the permanent equipment of a library and is a vitally important part; economy in its construction may easily be carried to excess.

Respectfully submitted,

Harrison W. Craver.

NECROLOGY

FREDERICK SARGENT

Frederick Sargent, senior member of the firm of Sargent & Lundy, of Chicago, and probably the most prominent consulting engineer in the United States specializing in the design of electrical generating sections, died at his home, in Glencoe, Ill., July 26, having been taken ill while abroad. An Englishman by birth, Mr. Sargent had made numerous trips to his native country, the last of which was made in April and May of this year in company with his close friend, Samuel Insull.

Frederick Sargent was born in Liskeard, Cornwall, England, on Nov. 11, 1859, which is also the exact date of the birth of Samuel Insull, another Englishman and Chicagoan, with whom Mr. Sargent was destined to be intimately associated during practically all of his engineering activities. His people were of the farming class, but young Sargent developed a decided mechanical bent, and eight years of his boyhood and youth were spent in acquiring practical mechanical knowledge and experience in the works of John Elder & Co., the great shipbuilders on the River Clyde, near Glasgow. During this time he gained an extensive and practical knowledge of mechanical engineering, paying particular attention to heavy machinery. He also improved his education by going to night school at Glasgow University. Coming to the United States about 1880, he found employment in Eastern shipbuilding yards as a designer of steam engines. He then went West as a designer for the Sioux City (Iowa) Engine Co. A year or so later he accepted a position with E. P. Allis & Co., of Milwaukee, predecessors of the present Allis-Chalmers Manufacturing Co. Here he attracted the attention of the officers of the Western Edison Light Co., organized in Chicago in 1882 to exploit the electric-lighting inventions of Thomas A. Edison in the West, and in the fall of 1884 he moved to Chicago and began his career as an electrical engineer in that city.

Succeeding the Western Edison Light Co., the Chicago Edison Co. was formed in 1887. This was the first distinctively Edison central-station company in Chicago. Mr. Sargent became its consulting engineer, and he has been consulting engineer of that company and its successor, the present Commonwealth Edison Co., ever since.

About 1889 he went to New York under contract with the Edison United Manufacturing Co. In this position he had general charge of all the work done by that company in the United States and Canada. Shortly after this the company in New York was reorganized as the Edison General Electric Co. Mr. Sargent was made assistant chief engineer of the new corporation, of which Samuel Insull was vice-president in charge of manufacturing. But Mr. Sargent had determined to open an office of his own, and, in August 1890 he returned to Chicago and established himself as an independent electrical and mechanical engineer. The firm of Sargent & Lundy was formed in 1891.

In 1891 and 1892 Mr. Sargent was consulting electrical engineer for the World's Columbian Exposition, and he designed the power plant and had much to do with the other mechanical and electrical features of the great World's Fair of 1893.

The original Edison central station in Chicago was built about 1889. Mr. Sargent made the plans for the machinery layout of that station. In 1892 Samuel Insull came to Chicago as president of the Chicago Edison Co., and that company at once took on a new lease of life. Under Mr. Insull's direction the old Harrison Street station, recently torn down to make way for the Union Station railroad improvements, was built. Mr. Sargent was the designer of that station, also the Fisk Street Station, the Quarry Street Station and the Northwest generating stations of the Commonwealth Edison Company.

He was one of the first mechanical engineers who recognized the great part that the steam turbine was destined to play in the development of electric generating stations. The Fisk Street Station was the pioneer of all the large turbine central stations of the world, and it became deservedly famous for its many original features of design and for its simplicity and economy of operation. After this station had been in operation for a short time, Mr. Sargent, at the request of Mr. Insull, President of the Commonwealth Edison Co., went to London to follow the inquiry of the Parliamentary Committee in charge of the London Power-Supply Bill. This hearing crystallized in Mr. Sargent's mind some ideas he had been developing about the importance of unified power supply for great industrial centers so as to reduce the cost of production, and on his return he submitted his ideas to Mr. Insull, and they were worked out in the power-station development of the Commonwealth Edison Company.

Mr. Sargent's engineering work was not confined to Chicago. He was consulting engineer for many of the important electric-light and power companies throughout the country, including the Edison Electric Illuminating Co., Boston; American Gas and Electric Co., New York; Electric Bond and Share Co., New York; the Union Gas and Electric Co., Cincinnati, and many other smaller organizations.

He designed the great combined central power station of the American Gas and Electric Co., and the West Penn Power Co., located on the Ohio River, north of Wheeling, W. Va., which was the first large electric station to be built in a favorable locality near a coal mine for the distribution of power to industrial centers at long distances.

He designed the great new station of the Union Gas and Electric Co., at Cincinnati, which was recently completed. He also designed the new station for the Kansas City Light and Power Co., which is soon to be put into operation. He went to Chile in 1916 as consulting engineer for the Guggenheim mining interests on the development of a power supply for their mine at Chuquicamata.

During the war Mr. Sargent was consulting engineer for the power station of the Edgewood Arsenal, at Edgewood, Md., and also consulting engineer for the United States Government in other wartime projects demanding the application of power on a large scale.

In his profession Mr. Sargent was noteworthy for the clear vision and strong common sense with which he grappled with the essentials of an engineering problem. He was simple, clear, direct and practical. He was a man of broad outlook, tolerant, modest, seeking to achieve results rather than to uphold theories. And he was eminently suc-

FREDERICK SARGENT

cessful in obtaining results, for his electrical generating stations were milestones of achievement in the economical production of electrical energy.

An idea of the esteem with which Mr. Sargent was held by his business associates was shown in an interview with Wm. S. Monroe, his friend and partner in the firm of Sargent & Lundy for many years, who said:

"Mr. Sargent had an exceptionally keen and active intellect and a vigorous and forceful personality. He was a man of absolute integrity and fearless independence and high idealism in his work. He had an infallible intuition regarding engineering and scientific matters, and the responsible men in the companies for which he was doing his engineering learned to place the utmost confidence in his judgment. He had a remarkable combination of extreme daring and careful conservatism. With a broad and ambitious view of important and fundamental principles of his engineering work, Mr. Sargent combined an accurate knowledge of all the underlying details, and no detail was too small for his personal attention.

"He kept in close touch with everything that was new in the engineering profession. He was a great traveler and made repeated trips to Europe as well as through this country in order to post himself on the important developments not only in the direct line of his own work but in all departments of the engineering field.

"His idealism was at times almost prophetic and he was very ambitious for the highest achievements in his work, but his idealism was held in restraint by a practical common-sense judgment, which combined to give a distinct originality to every new power station which he designed, and made it systematic and harmonious, economical and a perfect working machine."

Mr. Sargent was awarded a medal by the World's Columbian Ex-

position in 1893. He was a member of the jury of awards in power engineering at the St. Louis Exposition of 1904. He was a member of several societies and clubs, including the Western Society of Engineers' University Club, Chicago Yacht Club, and the Engineers' Club, New York. He became a member of our Society in 1901.

He is survived by a widow, one daughter and two sons.

WILLIAM A. BOLE

William A. Bole, Assistant to Vice-President H. T. Herr of the Westinghouse Electric & Manufacturing Co., Machine Works, died at his home in Pittsburgh on June 16. Mr. Bole was born on July 12, 1859, in Pittsburgh, Pa. He received his early education in the schools of Allegheny, later attending the University of Western Pennsylvania, now the University of Pittsburgh.

In 1878 he left school and was employed by his father who at that time was a manufacturer of steam engines in Pittsburgh. Here he gained considerable information regarding the manufacture of the mechanical parts of steam engines. After serving his father for three years he entered the employ of the Westinghouse Machine Co. in 1882 in the capacity of cost and time clerk. In 1883 he became foreman of the company and the following year was appointed Superintendent of Works and Purchasing Agent and in 1900 Manager of Works. In 1906 he was advanced to the position of Consulting Engineer and in 1908 became General Manager. In 1914 he was appointed Vice-President in Charge of Manufacture for the Machine Works and Trafford City Foundry. He was a veteran of thirty-seven years with the company.

Mr. Bole was a member of the Engineers' Society of Western Pennsylvania, of which he was president for one year, and of the American Foundrymen's Association. He became a member of our Society in 1887.

ALLEN EUGENE NICHOLS

Allen E. Nichols, of the firm of E. M. Nichols & Sons, Philadelphia and Chicago, died at his home in the latter city of pneumonia on May 8, 1919. Mr. Nichols was born on September 30, 1888, in Madison, Wis. He was graduated from Purdue University in 1910 with the degree of B. S. and in 1913 received his C. E. degree. He was formerly employed by the Baltimore & Ohio Railroad, R. L. Sackett, consulting engineer for the State of Indiana, the Chicago & Western Indiana Railroad and the firm of Alvord & Burdick, consulting engineers. From 1915 to 1918 he was engineer in direct charge of design, specifications and contracts for the Bureau of Waste Disposal for the City of Chicago. Owing to a permanent injury, Mr. Nichols was not accepted by the military authorities for enlistment in the Army, whereupon he entered the employ of the DuPont Engineering Co. as engineer of construction for a seventy-million-gallon water-filtration plant for the Government powder factory at Old Hickory Works, Nashville, Tenn., which position he retained until construction was completed. Early in the present year he entered into the general engineering and contracting business in conjunction with his father and brother.

Mr. Nichols was an associate member of the American Society of Civil Engineers and was a member of the Franklin Institute, the American Water Works Association and the Sons of the American Revolution. He became an associate-member of the Society in 1917.

PERSONALS

In these columns are inserted items concerning members of the Society and their professional activities. Members are always interested in the doings of their fellow-members, and the Society welcomes notes from members and concerning members for insertion in this section. All communications of personal notes should be addressed to the Secretary, and items should be received by September 15 in order to appear in the October issue.

CHANGES OF POSITION

MAURICE L. BULLARD, formerly associated with L. H. Shattuck, Inc., Manchester, N. H., has become affiliated with the Atlantic Corporation, of Portsmouth, N. H., as superintendent of the marine department.

FREDERICK R. PRATT has resigned as mechanical superintendent with D. Goff and Sons, Pawtucket, R. I., and has accepted the position of engineer with B. B. and R. Knight, of Providence, R. I.

WILLIAM H. CHURCHMAN has severed his connection with the East Bay Water Company, Oakland, Cal., as superintendent of pumping stations, and has assumed the duties of constructing and erecting engineer of steam, electrical and hydraulic machinery with the California Hydraulic Engineering and Supply Company, of San Francisco, Cal.

LEWIS S. MAXFIELD, until recently assistant to the secretary of the Heating and Piping Contractors National Association, has resigned to accept a position in the office of the mechanical engineer, New York Central Railroad.

CHARLES C. TRUMP, formerly with the Humphrey Gas Pump Company and Stumpf Una-Flow Engine Company, Inc., Syracuse, N. Y., is now employed by the Fuller-Lehigh Company, of Fullerton, Pa., and the Fuller Engineering Company, of Allentown, Pa., as sales engineer in the New York office.

CHARLES O'C. SLOANE has resigned his connection with the Allied Machinery Company of America, New York, and has joined the sales organization of the Betts Machine Company, of Rochester, N. Y.

WILFORD L. STORK, formerly metallurgist of the Michigan Motor Casting Company, Division of Buick, Flint, Mich., has resigned and is now associated with the Detroit Valve and Fitting Company, of Wyandotte, Mich., in the capacity of foundry superintendent.

LAWRENCE T. CUMMINGS, one of the senior engineers of Miller, Franklin, Basset and Company, consulting industrial and production engineers of New York City, has resigned his position in order to assume the duties of vice-president with the firm of Drefs, Cummings and Drefs, Inc., business consultants, Detroit, Mich.

CHARLES H. SCHMALZ has assumed the position of assistant factory manager with the Holt Manufacturing Company, of Peoria, Ill. He was, until recently, associated with the Hanna Engineering Works, Chicago, Ill., in the capacity of superintendent.

JOSEPH B. LINCOLN, formerly mechanical engineer, Naval Engineering Experiment Station, Annapolis, Md., has become affiliated with the New Departure Manufacturing Company, Bristol, Conn.

WILLIAM H. HAZARD has resigned his position as designing mechanical engineer for the Hercules Powder Company and has accepted the position of industrial engineer for the General Motors Corporation, assigned to work at the Janesville Machine Company and Samson Tractor Company plants.

CECIL R. HUBBARD has resigned his position of designing engineer with the National Metal Molding Company, Ambridge, Pa., and has taken up industrial engineering work with the Revere Rubber Company, Providence, R. I.

FRANCIS J. MCGRAIL, formerly of the Henry R. Worthington Pump Company, Harrison, N. J., and for eight years employed as foundry superintendent of the Struthers-Wells Company, Warren, Pa., has resigned his position to take charge of the iron and brass foundries operated by the Honolulu Iron Works Company, of Honolulu, Hawaii. Mr. McGrail assumed his new duties May 1.

A. L. VALENTINE, who for 19 years was connected with the small tool department of the Pratt and Whitney Company, Hartford, Conn., the last 15 as superintendent, has resigned. He sailed for France recently to become works manager of the Société des Usines Curial, Paris, France, manufacturer of small tools.

ELLWOOD A. METZ, formerly with the De Laval Steam Turbine Company of Trenton, N. J., has become associated with F. X. Hooper Company, Inc., Glanarm, Md., in the capacity of superintendent.

WILLIAM T. CLARK has left the employ of the Moline Plow Company, Moline, Ill., and has assumed the duties of factory manager with The Fuller and Sons Manufacturing Company, Kalamazoo, Mich.

P. J. BRYANT, formerly chief engineer, U. S. Military Academy, West Point, N. Y., has become affiliated with the Wabash Ice and Fuel Company, Wabash, Ind.

ALFRED L. FITCH has become associated with the Ashton Valve Company, Cambridge, Mass., in the capacity of mechanical engineer. He was until recently designer with the Blanchard Machine Company, Cambridge, Mass.

F. G. HECHLER has resigned his position as mechanical engineer at the U. S. Naval Engineering Experiment Station, Annapolis, Md., and has become associated with the Vibration Specialty Company, Philadelphia, Pa., as engineer and superintendent.

ANNOUNCEMENTS

J. J. BROWN, formerly vice-president and general manager of the Wheeler Condenser and Engineering Company, Carteret, N. J., was elected president of the company succeeding Charles W. Wheeler, recently deceased.

F. B. WILLIAMS has been discharged as Captain in the Ordnance Department, U. S. A., after two years' service and has accepted a position as assistant superintendent of the Watertown, Mass., plant of the Walker and Pratt Manufacturing Company.

John B. Price has been transferred from the managership of the Cincinnati office of the Refinite Company and now has charge of the New York office of the company.

Otto R. Kihm, formerly associated with the American Can Company, Edgewater, N. J., in the capacity of chief mechanical engineer, has started in business for himself under the firm name of the Kihm-Bowen Machine Company, Irvington, N. J., specializing in sheet metal working machinery, shear blades and re-grinding shear blades.

R. Sanford Riley, of Worcester, Mass., has gone to England and the Continent in the interest of the Sanford Riley Stoker Company and the Norton Company. Mr. Riley was appointed honorary vice-president to represent the A. S. M. E. at the James Watt Centenary, held at Birmingham, England, the latter part of August.

Thayer P. Gates, consulting engineer and textile specialist, announces the opening of offices in Providence, R. I. He will handle mill and power plant engineering, appraisal and special reports, operation and management, production engineering and textile engineering.

Webster Tallmadge has been transferred to the service department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. He was, until recently, connected with the Boston office of the company, as superintendent of the steam division.

E. H. Bull, associated with the Green Engineering Company, East Chicago, Ind., for seven years as engineer, is a member of the firm of Bull and Liversparger which has been appointed sales representative of the Green Engineering Company in Chicago and northern Illinois territory.

I. D. Everitt, recently discharged from the U. S. Army, is the New England manager for the Blackmer Rotary Pump Company. He is located in Boston, Mass.

Harry I. Lewis has been discharged from military service as first lieutenant in the Ordnance Department and has become connected with the firm of Bishop and Babcock Company, Cleveland, Ohio, in the capacity of chief engineer in the refrigeration division.

George H. Diman, formerly with the American Woolen Company's mills of Lawrence, Mass., has retired from active duty with this company after 32 years of continuous service. He is still retained by them as a member of the general advisory board.

Fred V. Larkin, assistant general superintendent of the Harrisburg Pipe and Pipe Bending Company, Harrisburg, Pa., formerly assistant professor of mechanical engineering in Lehigh University, will return to Lehigh as professor of mechanical engineering on September 1, to fill the chair vacated by the death of Prof. J. F. Klein, head of that department for many years.

Parry Keller has received his discharge as a first lieutenant, Ordnance Department, U. S. A., and has accepted a position with the Goodyear Tire and Rubber Company, Akron, Ohio, in connection with the development and manufacture of tires and tubes.

Walter W. Tangeman, Major, Ordnance Department, has recently returned from service in France, and has become re-associated with the Cincinnati Milling Machine Company, Cincinnati, Ohio, in the capacity of sales engineer.

L. F. Graef has become affiliated with the Compania Minera del Mirasol, S. A., Cusihuiriachic, Chihuahua, Mexico.

R. R. Shafter has returned to the sales organization of Traylor Engineering and Manufacturing Company, mining, milling, crushing and smelting equipment, Allentown, Pa., after an absence of two years as general superintendent of the Traylor Shipbuilding Corporation. Mr. Shafter as district manager will have charge of the New York office.

M. M. Shuster has become production engineer with the Clip-Bar Manufacturing Company, Philadelphia, Pa., manufacturers of the Shuster Speed Wrench. Mr. Shuster was recently discharged from the Naval Air Service.

Howard Coonley, president of the Walworth Manufacturing Company, Boston, Mass., has been elected a vice-president of the Massachusetts Credit Union Association.

Captain Edward Van Winkle, recently regimental engineer officer of the 24th Engineers, American Expeditionary Forces, desires to announce that he has resumed his practice as consulting engineer and has formed an association with Frederick A. Waldron, consulting engineer, New York, for the general practice of engineering with special reference to the problems relating to the construction, development and operation of industrials.

David S. Wegg, Jr., has left the Army Ordnance, where he was chief examiner, Chicago District Claims Board, and has become testing engineer for the Isko Company, Chicago, Ill., manufacturers of electric refrigerating machinery.

Robert P. Lay has accepted a position with the H. H. Franklin Manufacturing Company, Syracuse, N. Y., in the capacity of special engineer in the engineering department.

Prof. Arthur M. Greene, Jr., was elected president of the Society of the Promotion of Engineering Education at the 27th annual meeting of the Society held in Baltimore, Md., during the last week of June.

L. E. Strothman, who for several years has been manager of the Steam Turbine and Pumping Department of the Allis-Chalmers Manufacturing Co., has left the firm and has become vice-president and general manager of the Richardson-Phenix Co., in which firm he has acquired a financial interest. J. W. Peterson, formerly vice-president and general manager of the Richardson-Phenix Co., has assumed the duties of president and treasurer of the company.

THE HORSE-POWER OF RESISTANCE IN AEROPLANE DESIGN

(*Continued from page 727*)

estimate on a four-motored machine, for which the fuel must now be computed at $10{,}150 \times 4/2 = 20{,}000$ lb. approx. The new machine weight can now be estimated as follows:

Fuel	20,000 lb.
Four motors and equipment........	3600 lb.
Crew (3 men).....................	450 lb.
Dead load (machine)............	8000 lb.
Total weight..................	32,050 lb.

The total weight would therefore be about 32,000 lb. The approximate wing area (R. A. F. No. 15) is given by the formula $32{,}000 = 0.002958 \times 3025 \times A$ (for 14 deg. angle of incidence) $= 3570$ sq. ft. The ratio of linear dimensions N is 1.77:1, and the ratio of weights m is 3.14:1.

Investigating the problem, we have

$N = 1.77$; $m = 3.14$, hence

$$V_a = \frac{\sqrt{3.14}}{1.77} V_b = V_b$$

i.e., the velocities correspond. Also,

$$\text{Thrust}_a = 3.14 \times \text{Thrust}_b$$

and

$$\text{HP}_a = \frac{3.14\sqrt{3.14}}{1.77}\text{HP}_b = 3.14\text{HP}_b$$

The original type had 800 hp. in two motors. If the new machine were to fly at 100 m.p.h., the effective L/D would be 5.50, which would considerably lower the radius of flight. However, at 80 m.p.h. a value of 6.90 may be realized for the L/D factor. Further, the horsepower requirement at this speed is 320, as compared to 600 for the basic machine. If the new machine be equipped with four motors of the high-compression type, the available horsepower $= 0.82 \times 4 \times 430 = 1410$. This is equivalent to the $1410/3.14 = 450$ hp. flying requirement in the basic machine—about 97 m.p.h. Hence a flying speed of 95 m.p.h. may be counted on, with an effective L/D of 6.0. If the course as laid out were 2000 miles and 300 were allowed for variation, the trip would require 24 hours. With the four motors running continuously the total weight of gasoline necessary would be $33 \times 4 \times 24 \times 6.15 = 19{,}500$ lb., whereas the contemplated quantity was 20,000 lb.

The flight could be successfully accomplished, then, with a flying boat, similar to existing types, of about 32,000 lb. in weight, equipped with four motors, and having a gasoline supply of about 3250 gal., assuming flight at continued full speed and at maximum r.p.m. of the four motors. At economical speed the gasoline supply necessary would be approximately 85 per cent, or 2760 gal.[1]

[1] The NC-4 (total weight, 28,000 lb.) flew 1390 miles in 15 hours 18 minutes and carried a gasoline load of 1650 gal.

LIBRARY NOTES AND BOOK REVIEWS

ABRASIVES AND ABRASIVE WHEELS. Their Nature, Manufacture and Use. A Complete Treatise on the Manufacture and Practical Use of Abrasives, Abrasive Wheels and Grinding Operations. By Fred B. Jacobs. The Norman W. Henley Publishing Co., New York, 1919. Cloth, 5 x 8 in., 338 pp., 174 illus., 1 por., $3.

This work opens with descriptions of the various natural and artificial abrasives, the manufacture of grinding wheels and artificial sharpening stones, the grades established in commerce and the methods of testing grinding wheels, dust-collecting systems and safeguards, abrasive papers and cloths, methods of surface, cylindrical and internal grinding, special grinding operations, and cutter and saw sharpening. The author writes from experience as a machinist and as a salesman of grinding wheels.

AIRPLANE DESIGN AND CONSTRUCTION. By Ottorino Pomilo. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 403 pp., 248 illus., 58 tables, $5.

A book on the structure and design of airplanes, in which the results of European experimental research in aerodynamics are presented in considerable detail. The problems relating to airplane design and operation are analyzed, working formulæ are derived and the data needed by designers are presented.

THE APPLICATIONS OF ELECTROLYSIS IN CHEMICAL INDUSTRY. By Arthur J. Hale. Longmans, Green & Co., New York, 1918. Cloth, 6 x 9 in., 148 pp., 56 illus., $2.50. (Monograms on Industrial Chemistry.)

The author describes briefly the electrolytic refining and winning of metals; the production of hydrogen and oxygen, chlorin, caustic soda, hypochlorites, chlorates and perchlorates; and of various other organic and inorganic compounds. References to the literature and patents are included.

A CENTURY OF SCIENCE IN AMERICA. With Special Reference to the American Journal of Science, 1818-1918. By Edward Salisbury Dana and Others. Yale University Press, New Haven, 1918. Cloth, 6 x 9 in., 458 pp., 22 por., $4.

The present book commemorates the one-hundreth anniversary of the founding of the *American Journal of Science* by Benjamin Silliman in July, 1818. The opening chapter gives a somewhat detailed account of the early days of the *Journal*, with a sketch of its subsequent history. The remaining chapters are devoted to the principal branches of science which have been prominent in the pages of the *Journal;* geology, paleontology, mineralogy, chemistry, physics, zoology and botany. They have been written with a view to showing in each case the position of the science in 1818 and the general progress made during the century. Special prominence is given to American science and particularly to the contributions to it to be found in the *Journal's* pages.

ELECTRICAL AIDS TO GREATER PRODUCTION. Plans, Methods and Appliances by Which Industrial Electrical Engineers are Meeting Increased Demands for Power. Compiled and edited by Allen M. Perry. First edition. Published by *Electrical World*, McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 332 pp., illus., chart, tables, $2.

Contents: General Power Problems of Industrial Plants; Distribution, Transformation, Switching and Protection; Motors, Control, Specific Applications, Troubles and Remedies; Illumination—Selection of Equipment, Economics, and Specific Applications; Electric Furnaces, Welding, etc.; Meters and Measurements as Applied to Industries; Handling Material in Industrial Plants with Electric Tractors; Outdoor Substations.

The engineering editor of the *Electrical World* has prepared this volume from the articles on the application of electricity to plants which have appeared in that periodical during the last few years. It summarizes the methods that have arisen from the necessity for increased factory output and reduced cost of production caused by the war in many classes of industries.

INDUCTION COILS IN THEORY AND PRACTICE. By F. E. Austin. (Hanover, N. H., copyright 1919.) Cloth, 6 x 9 in., 64 pp., 45 illus., $1.

A presentation of the fundamental principles of the induction coil, for use as a textbook. Intended to enable the student to construct induction coils to meet a variety of demands as well as to construct coils to fulfill specific requirements.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS. By Emil Hatschek. Third edition. P. Blakiston's Son & Co., Philadelphia, 1919. Cloth 5 x 7 in., 116 pp., 17 illus., $1.50.

This small volume is intended to introduce readers with a reasonable knowledge of physics and chemistry to the fundamental facts and methods of this important branch of physical chemistry. Small additions and corrections have been made to this edition, to include such recent advances as fall within the scope of a brief introductory work.

JAMES WOODHOUSE, A PIONEER IN CHEMISTRY, 1770-1809. By Edgar F. Smith. The John C. Winston Co., Philadelphia, 1918. Cloth, 5 x 8 in., 299 pp., 1 pl., 1 por., $1.50.

Dr. Smith's account of the life and labors of James Woodhouse is a valuable contribution to the early history of chemistry in America. Woodhouse was elected professor of chemistry at the University of Pennsylvania in 1795 and retained this connection until his death in 1809. He was an industrious and ingenious chemist, who by his work and writings did much to establish the teaching of chemistry on a sound basis and to arouse interest in the industrial applications of the science.

LABORATORY EXPERIMENTS WITH DIRECT CURRENTS. By F. E. Austin. (Hanover, N. H., copyright 1917). Flexible cloth, 5 x 7 in., 152 pp., illus.

A laboratory course, covering about forty hours, for students in technical and industrial high schools, etc., based on the author's experience as a teacher. The chief aim is to make evident some of the engineering applications of direct currents.

MACRAE'S BLUE BOOK. MacRae's Blue Book Co., New York, 1919. Cloth, 9 x 12 in., 1846 pp., $10.

This record of manufacturers is intended for use by purchasing agents interested in iron and steel products, building materials, railway supplies, etc. It includes an alphabetical address list of the principal manufacturers in the United States, a classified index of the makers of 10,000 products, an index of trade names, a collection of miscellaneous data useful to purchasers and users of the articles considered, and the standard list prices of building materials, iron and steel products, etc.

MILITARY GEOLOGY AND TOPOGRAPHY. A Presentation of Certain Phases of Geology, Geography and Topography for Military Purposes. Herbert E. Gregory, Editor. Prepared and issued under the auspices of the Division of Geology and Geography, National Research Council. Yale University Press, New Haven, 1918. Cloth, 6 x 9 in., 281 pp., illus., pl., maps, $1.25.

This book is the result of a preliminary effort to meet the need which the Great War has demonstrated for a more widely diffused knowledge of geology as an aid in conducting military operations and in the solution of economic problems relating to raw materials. Attention is given mainly to those facts and principles that have proven to be applicable to military problems. Bibliographies for supplementary reference study are included.

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American Bureau of Shipping. Extract from the Rules for Building and Classing Vessels. Sections 39-42, inclusive, and Sec. 49. 1917. Revised June 1918. Gift of Bureau.

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Bibliography of the Occurrence, Geology and Mining of Manganese with Some References on its Metallurgy and Uses. Compiled by Harold L. Wheeler. Reprint. Gift of author.

Managing for Maximum Production. By L. V. Estes. Pts. I, II and III. Reprints. Gift of author.

Marine and Dock Labor—Work, Wages, and Industrial Relations During the Period of the War. Report of the Director of the Marine and Dock Industrial Relations Division, U. S. Shipping Board. 1918. Gift of Board.

Mechanics' and Engineers' Pocket-Book. By Chas. H. Haswell. 60th edit. *1895*. Gift of Prof. F. R. Hutton.

Missouri Bureau of Geology and Mines. Biennial Report of the State Geologist. *1919*. Purchase.

Monograph on the Constitution of Coal. Dept. of Scientific and Industrial Research. *London, 1918.* Purchase.

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State of New York. Second Report of the Factory Investigating Commission. Vols. 1 & II. *1913*. Gift of Prof. F. R. Hutton.

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